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ATTITUDE SEQUENCE FOR THE APOLLO 8 SPACECRAFT OPERATIONAL TRAJECTORY



Lunar Mission Analysis Branch

MISSION PLANNING AND ANALYSIS DIVISION



MANNED SPACECRAFT CENTER HOUSTON, TEXAS

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PROJECT APOLLO

ATTITUDE SEQUENCE FOR THE APOLLO 8 SPACECRAFT OPERATIONAL TRAJECTORY

By Mission Design Section TRW Systems Group

November 22, 1968

MISSION PLANNING AND ANALYSIS DIVISION NATIONAL AERONAUTICS AND SPACE ADMINISTRATION MANNED SPACECRAFT CENTER HOUSTON, TEXAS

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ATTITUDE SEQUENCE FOR THE APOLLO 8 SPACECRAFT OPERATIONAL TRAJECTORY

By Mission Design Section TRW Systems Group

1. SUMMARY AND INTRODUCTION

1.1 General

This document presents the operational attitude sequence for the C-prime lunar orbit mission. The spacecraft attitude data and event sequence contained in this report reflect current philosophy in areas pertinent to the development of the mission attitude timeline. This philosophy was formulated primarily through analysis and working group meetings with appropriate MSC and contractor personnel. The basic techniques and procedures as agreed upon through these discussions are subject to revision resulting from operational aspects of the mission attitude profile. Any such revisions will be published as addenda to this document.

The spacecraft operational attitude data are presented in the following format:

- 1. Discussion of the major attitude events occurring during the mission
 - 2. Figures illustrating the attitude events
- 3. Mission attitude timeline indicating the chronological sequence of events (Table I). Event times for the mission were obtained from the Apollo 8 Preliminary Flight Plan, Reference 1.
- 4. Tabular data summarizing the pertinent parameters of interest (Table II)

1.2 Trajectory Profile

The spacecraft operational trajectory furnishing the state vector and ephemeris data for generating the required attitude data was obtained from the Lunar Mission Analysis Branch of MPAD-MSC. The trajectory was precision integrated on the Apollo Reference Mission Program Version ARM06. Launch date for the trajectory was 21 December 1968 with a launch azimuth of 72 degrees.

Major events in the mission include the launch to insertion into a 100-nautical mile altitude earth parking orbit. A Pacific injection on the second revolution in earth orbit initiates the translunar phase of the mission. The translunar and transearth phases are characterized by relatively short flight times of approximately 66 hours and 85 hours, respectively. The lunar orbit phase consists of ten revolutions in lunar orbit devoted primarily to optical navigation and photography assignments.

1.3 Attitude Data Generation

The attitude data required to analyze and define the various space-craft attitude events were produced using the Apollo Mission Attitude Requirements (AMAR) Program. It should be noted that attitude maneuvers which reorient the spacecraft from an existing attitude are performed instantaneously in the AMAR simulation of the attitude event sequence. Maneuver times are shown for the applicable maneuvers in the cislunar portion of the timeline with the previous attitude carried through to the instantaneous initiation of the new orientation. The maneuver times are best estimates and are not intended to reflect actual reorientation procedures. Lunar orbit attitude maneuvers are shown at the initiation time for the reorientation since the operational maneuver procedures have not been defined for this phase of the mission.

1.4 Constraints

To facilitate discussion of the attitude event timeline, the primary spacecraft attitude constraints applicable to various phases or events in the mission are listed in this section.

1.4.1 Earth parking orbit constraints. -

- 1. The CSM attitude must provide continuous tracking, command, telemetry, and voice capabilities when line of sight to a MSFN station exists.
- 2. CSM gimbal lock must be avoided. For this mission, gimbal lock has been defined as an angle of 45 degrees or less between the outer gimbal axis and the inner gimbal axis.

1.4.2 Cislunar constraints. -

- 1. Continuous S-IVB tracking and telemetry are required for a 10-minute period within the first 20 minutes after TLI cutoff.
- 2. S-IVB tracking, telemetry and command and CSM tracking, telemetry and voice are required during the S-IVB/CSM separation maneuver.
- 3. Telemetry is required from the S-IVB for a minimum of 10 minutes following S-IVB/CSM separation.

- 4. CSM tracking, command, telemetry, and voice are required for one hour following S-IVB/CSM separation.
 - 5. CSM gimbal lock must be avoided.
- 6. The S-IVB attitude at S-IVB/CSM separation must provide illumination of the forward end of the S-IVB to simulate the lighting for the LM extraction maneuver.
- 7. For midcourse correction (MCC) maneuvers, continuous CSM command, telemetry, and voice are required for the 1-hour period beginning 30 minutes before the MCC.
- 8. The maximum duration of a continuous attitude hold for the CSM cannot exceed 1 hour. This is a fracture mechanics limit imposed by the RCS propellant tanks in a hot environment.
- 9. The ratio of thermal control time to attitude hold time should be at least 5 to 1.
- 10. For IMU alignments, the CSM inertial attitude must provide a suitable starfield for the optics field of view.
- 11. For IMU alignments, the sun line of sight must not be within 15 degrees of the sextant (SXT) boresight nor within 55 degrees of the scanning telescope (SCT).
- 12. For cislunar optical navigation, the sun line of sight must not be within 10 degrees of the landmark line of sight nor within 15 degrees of the star line of sight for the SXT.
- 13. For periods of passive thermal control (PTC), the CSM should be oriented as near broadside to the earth as possible to optimize omni antenna-earth communications.
- 1.4.3 <u>Lunar orbit constraints</u>. There are no unique CSM attitude constraints for the lunar orbit phase of the mission. Attitude requirements pertaining to cislunar optical navigation, IMU alignments, gimbal lock avoidance, and MSFN communications must be satisfied by appropriate attitude orientations in lunar orbit. Violation of any of these constraints (usually communications) to meet mission objectives are pointed out in the discussion.

2. SYMBOLS

ALT altitude ARM06 Apollo Reference Mission Program Version ARM06 AMAR Apollo Mission Attitude Requirements Program AOS acquisition of signal CMcommand module command and service module **CSM** EMP earth-moon plane ground elapsed time (hr:min:sec) g.e.t. **IGA** inner gimbal angle IMU inertial measurement unit LAT selenographic latitude LMlunar module LMAB Lunar Mission Analysis Branch LOI-1 first lunar orbit insertion burn lunar orbit circularization burn LOI-2 selenographic longitude LON LOS loss of signal MCC midcourse correction middle gimbal angle MGA Mission Planning and Analysis Division-Manned MPAD-MSC Spacecraft Center **MSFN** Manned Space Flight Network outer gimbal angle **OGA** PTC passive thermal control

reaction control system

RCS

REFSMMAT reference to stable member coordinate transformation

SCT scanning telescope

SDA shaft drive axis

SEH star/earth horizon

SEL star/earth landmark

SLA spacecraft LM adapter

SLH star/lunar horizon

SLL star/lunar landmark

SM service module

SPS service propulsion system

SXT sextant

S-IVB third stage of Saturn V vehicle

TE transearth

TEI transearth injection

TL translunar

TLI translunar injection

ΔV velocity increment

3. EARTH ORBIT PHASE

The S-IVB/SLA/CSM configuration is inserted into a 100-nautical mile altitude circular parking orbit by the Saturn V booster at 00:11:20 g. e.t. The burnout attitude is held inertially fixed for 15 seconds after termination of the insertion burn. Following this hold, the S-IVB attitude control system positions the S-IVB (and CSM) X-axis along the local horizontal in the direction of motion. The CSM Z-axis is in the trajectory plane with the crew heads down. An S-IVB orbital pitch rate is then initiated in order to maintain this alignment locally fixed during the earth orbit phase of the mission. This attitude assures communication coverage during passes over MSFN stations. During the second revolution in earth parking orbit, the S-IVB will orient to the TLI burn attitude. The burn is performed under attitude control by the S-IVB guidance and control systems.

It should be noted at this point that the IMU gimbal angle data shown in the tables are based on the prelaunch REFSMMAT until the IMU is realigned prior to the last TL MCC. Gimbal angle measurements after this realignment will reflect the new IMU attitude reference as will be discussed in the appropriate section. Table III lists the direction cosines corresponding to the three IMU REFSMMAT alignments which are unique for the given launch date and launch azimuth.

Table II(a) lists the spacecraft position and attitude data for the earth orbit phase of the mission.

4. TRANSLUNAR PHASE

This section contains a brief description of major attitude events in the translunar phase of the mission. Most of these events, as noted in their descriptions are also common to the transearth phase of the mission. Those events occurring only in the transearth phase will be described in Section 6. A graphical presentation of the major cislunar events is given in Figure 1. Spacecraft look angles and IMU gimbal angles for the translunar phase are given in Table II(b).

4.1 Post-TLI Sequence of Events

Following the termination of the TLI burn at 02:55:43 g.e.t., the burnout attitude is fixed inertially for 20 seconds. At the end of this time period, the local horizontal mode is again established by the S-IVB attitude control system for MSFN post-TLI checkout. Fifteen minutes after TLI cutoff, the S-IVB orients to the S-IVB/CSM separation attitude. Primary considerations involved in defining the separation attitude are communications, gimbal lock, and lighting on the forward end of the S-IVB. The lighting constraint is to evaluate illumination of the LM docking tunnel for later missions having the LM onboard. The orientation thus consists of a pitch maneuver to point the SLA generally towards the sun and a roll maneuver for communications. The separation attitude is held inertially fixed until a separation distance of about 50 feet is achieved between the S-IVB and CSM. The CSM is then pitched through 180 degrees to face the S-IVB. This attitude provides visual observation of the S-IVB and MSFN communications. A roll maneuver of minus 60 degrees is executed from this attitude for the proper docking alignment. The CSM station-keeps at this attitude for approximately 13 minutes and then orients to the evasive maneuver attitude. This attitude consists of the CSM X-axis being aligned along the negative position vector. The CSM minus Z-axis is oriented in the direction of motion and in the trajectory plane. The purpose of the orientation is to provide visual monitoring of the S-IVB venting and a nominal thrusting alignment for an RCS burn to avoid S-IVB recontact.

The evasive maneuver attitude is held inertially fixed until 05:07:43 g.e.t., at which time the CSM will be positioned to observe the S-IVB slingshot trajectory. The CSM attitude for this event aligns the CSM X-axis 18 degrees below the negative velocity vector. Communications coverage is optimized by minimizing the angle between the negative position vector and the S-band antenna boom. The CSM monitoring attitude is fixed inertially for approximately one hour.

The post-TLI sequence of events is illustrated in Figure 2. Numerical data for the post-TLI sequence were obtained from Reference 2.

4.2 Navigation Sightings

During the cislunar phase of the mission, optical navigation will be performed to determine onboard navigation capability. These sightings occur throughout the mission as noted in the tabular data. The various types of cislunar navigation sightings are

- 1. Star/earth horizon sightings optical sightings taken on a reference star and the lighted earth horizon
- 2. Star/earth landmark sightings optical sightings taken on a reference star and a known or unknown earth landmark
- 3. Star/lunar horizon sightings optical sightings taken on a reference star and the lighted lunar horizon
- 4. Star/lunar landmark sightings optical sightings taken on a reference star and a known or unknown lunar landmark

The CSM orientation for optical sightings must consider requirements for communications and avoidance of gimbal lock as well as the optical pointing requirements. Sightings involving the earth horizon or landmarks can usually be accomplished at an attitude satisfying these requirements. This is caused by the fact that the CSM optics and S-band antenna are only 48 degrees apart and point in the same general direction. Lunar navigation sightings, however, produce attitudes inconsistent with S-band communications requirements for the same reason. Figure 3 illustrates the geometrical situation for both earth and lunar navigation sightings.

4.3 Passive Thermal Control

A nominal thermal environment is provided during the cislunar phase for temperature-critical spacecraft components by the passive thermal control (PTC) mode. The CSM PTC orientation consists of aligning the CSM X-axis normal to the solar vector and rolling about the X-axis at two revolutions per hour. Attitude control is maintained in wide angle deadband (±5 degrees) in pitch and yaw when the PTC attitude is established. Roll axis control may then either be maintained or disabled. For simulation purposes in this timeline, the X-axis pointing was fixed.

The PTC orientations have also been optimized for omni antenna coverage by positioning the X-axis as broadside to the earth as possible without violating the middle gimbal angle constraint. Figure 4 shows this orientation procedure.

It may be noted by referring to the tabular data that the lunar mission rule requiring a 5 to 1 ratio of PTC time to attitude-hold time is not satisfied for the major portion of this timeline. This is due primarily to the short translunar and transearth flight times. During the mission, the thermal control requirement could be met to some degree by roll maneuvers to reorient the spacecraft between star sightings.

4.4 IMU Alignments

Prior to the midcourse correction (MCC) maneuvers, lunar orbit insertion, and entry, the crew will realign the IMU to preclude drift errors in targeting for these events.

The CSM cislunar IMU alignment attitude is involved primarily with obtaining a suitable starfield for the CSM optics. For generation of this attitude timeline, it has been assumed that the attitude preceding each IMU alignment (with the exception of the pre-LOI alignment) which is usually a navigation sighting attitude is acceptable for performing the alignment. This assumption implies that a suitable starfield should be available with the existing attitude. In the event of earth or lunar occlusion at this attitude, a roll maneuver could be employed to obtain a clear optics field of view.

4.5 Midcourse Corrections

At specified times during the translunar and transearth phase of the mission, the ground will determine by state vector propagation if the current trajectory will satisfy desired end conditions. If the trajectory is deemed unacceptable, a midcourse correction maneuver will be performed by either the SPS or the RCS.

Since the MCC attitude is dependent on the type of adjustment maneuver required, this attitude cannot be described prior to the mission. This timeline has, therefore, assumed each MCC occurs in the previous attitude (IMU alignment) with a ΔV for the maneuver of zero.

4.6 Pre-LOI Sequence of Events

The IMU alignment prior to the last translunar MCC will align the IMU to the LOI-2 REFSMMAT. The IMU alignment is to provide the crew with gimbal angles of 0, 180, 0 (roll, pitch, yaw) at the start of the LOI-2 burn.

After the time for the last translunar MCC, the CSM is aligned to the PTC orientation. Approximately 5 hours later, another IMU alignment is performed, after which the PTC mode is resumed. Approximately 1-1/2 hours later, the CSM is oriented to the LOI-1 burn attitude, and another IMU alignment is performed. This attitude is held inertially fixed through the LOI-1 burn.

5. LUNAR ORBIT PHASE

A detailed description of each revolution is included for the lunar orbit portion of the attitude sequence because of the many and varied events which occur. Instantaneous maneuvers have been shown because operational procedures are not as yet defined. The mission time of the maneuver should be regarded as the time of initiation of the attitude maneuver. A sufficient time interval has been allowed between the instantaneous maneuver and the following event for which the maneuver was required. Table II(c) presents the spacecraft positional and attitude data for the lunar orbit phase of the mission.

5.1 First Revolution (Figure 5)

The sequence of significant events that occur during the first revolution is as follows:

- 1. First lunar orbit insertion (LOI-1) burn
- 2. Acquisition of MSFN line of sight
- 3. Enter darkness
- 4. IMU realignment
- 5. Loss of MSFN line of sight
- 6. Enter sunlight
- 7. Lunar observation and photography

The LOI-1 burn deboosts the CSM from the cislunar trajectory into a 60-nautical mile by 170-nautical mile elliptical parking orbit. The burn is performed with the CSM in a retrograde attitude, and the crew is heads down to afford visual reference with the lunar surface. The LOI-1 burn attitude is held inertially fixed until immediately prior to acquisition of MSFN line of sight. The CSM is then rolled 180 degrees to establish S-band communications. The resulting attitude is held inertially fixed until loss of MSFN line of sight. This inertially fixed attitude satisfies the attitude requirements for the IMU realignment which occurs immediately after the CSM enters darkness. At the loss of MSFN line of sight, the CSM is maneuvered to an attitude which allows lunar visual observation and photography. The vehicle attitude, with respect to the local horizontal orientation, is a pitch of minus 45 degrees and a roll of 180 degrees. This attitude is held locally fixed through the completion of the first revolution.

This attitude sequence allows S-band communications from the acquisition of MSFN line of sight to the loss of MSFN line of sight.

5.2 Second Revolution (Figure 6)

The sequence of significant events that occur during the second revolution is as follows:

- 1. Lunar observation and photography
- 2. Acquisition of MSFN line of sight
- 3. Enter darkness
- 4. IMU realignment
- 5. Loss of MSFN line of sight
- 6. Enter sunlight

At the completion of the first revolution, the CSM is in a locally fixed attitude which allows lunar visual observation and photography. The local attitude hold is maintained until approximately 7 minutes prior to the CSM entering into darkness. At this time, the local attitude hold is terminated, and the existing vehicle attitude is held inertially fixed. This inertially fixed attitude satisfies the attitude requirements for the IMU realignment which occurs about 5 minutes after the CSM enters darkness. Approximately 8 minutes prior to the loss of MSFN line of sight, the inertial attitude hold is terminated, and the CSM is maneuvered to the circularization (LOI-2) burn attitude. The CSM is first maneuvered to an attitude which is rolled 180 degrees from the burn attitude to allow S-band communications. After the loss of MSFN line of sight, the CSM is rolled minus 180 degrees into the circularization burn attitude. This attitude is held inertially fixed through the remainder of the second revolution.

This attitude sequence allows S-band communications from the acquisition of MSFN line of sight to the loss of MSFN line of sight.

5.3 Third Revolution (Figure 7)

The sequence of significant events that occur during the third revolution is as follows:

- 1. Circularization burn
- 2. Landmark familiarization
- 3. Acquisition of MSFN line of sight
- 4. Pseudo landing site landmark familiarization and photography
- 5. Enter darkness

- 6. IMU realignment
- 7. Loss of MSFN line of sight
- 8. Enter sunlight
- 9. Orbital navigation photography

Immediately following the start of the third revolution, the circularization burn is performed. The circularization burn transforms the initial elliptical parking orbit into a 60-nautical mile circular orbit. The burn is performed with the CSM in a retrograde attitude, and the crew is heads down to afford visual reference with the lunar surface. After the burn, the CSM burn attitude is held inertially fixed for approximately 10 minutes. The CSM is then maneuvered to an attitude which allows landmark familiarization and photography. In this exercise, the CSM X-axis cameras are given the same pointing profile that the CSM shaft drive axis (SDA) will have during landmark sightings. The vehicle attitude, with respect to the local horizontal orientation, is a pitch of minus 52.5 degrees and a roll of 180 degrees. This attitude is held locally fixed until the CSM cameras become pointed at the pseudo landing site landmark (Table IV). A manual pitch rate is then initiated to keep the cameras pointed at the landmark. Approximately 1.5 minutes after the CSM passes the closest point of approach to the landmark, the pitch rate is terminated, and the vehicle is pitched minus 70 degrees. The resulting attitude is held inertially fixed. This inertially fixed attitude satisfies the attitude requirements for the IMU realignment occurring approximately 7 minutes after the CSM enters darkness. The inertial attitude hold is maintained until approximately 19 minutes before the CSM enters sunlight. The inertial attitude hold is then terminated, and the CSM is maneuvered to an attitude which allows orbital navigation photography. The vehicle attitude, with respect to the local horizontal orientation, is a pitch of minus 90 degrees and a roll of 180 degrees. This attitude is held locally fixed while the CSM X-axis cameras perform vertical stereo photography. The CSM windows are oriented away from the sun to allow better photography. This attitude is held locally fixed through the completion of the third revolution.

Except for a small period of time during the photography of the pseudo landing site landmark, this attitude sequence allows S-band communications from the acquisition of MSFN line of sight to the maneuver to the orbital navigation photography attitude.

5.4 Fourth Revolution (Figure 8)

The sequence of significant events that occur during the fourth revolution is as follows:

- 1. Orbital navigation photography
- 2. Acquisition of MSFN line of sight

- 3. Landmark lighting evaluation
- 4. Enter darkness
- 5. IMU realignment
- 6. Loss of MSFN line of sight
- 7. Enter sunlight

At the start of the fourth revolution, the CSM is in the locally fixed orbital navigation photography attitude. The local attitude hold is maintained, and the vehicle is rolled minus 180 degrees as it passes over the sub-solar point to orient the windows away from the sun. Approximately 13 minutes before the CSM passes the closest point of approach to the pseudo landing site landmark, the CSM is maneuvered to the initial tracking attitude for the Mode III type landmark sighting attitude sequence (Figure 9). The attitude at the beginning of a Mode III type tracking sequence, with respect to the local horizontal orientation, is a pitch of 5 degrees. This attitude is maintained locally fixed until the CSM is about 3 minutes from the closest point of approach to the landmark. The CSM is then given a minus 0.3-degree per second pitch rate to keep the landmark in the optics field of coverage throughout the tracking period. Approximately 1.5 minutes after the CSM passes the closest point of approach to the landmark, the pitch rate is terminated. This Mode III type tracking sequence is used for the landmark lighting evaluation of the pseudo landing site landmark. After the tracking sequence is terminated. the CSM is rolled 180 degrees to gain S-band communications, and the resulting attitude is held inertially fixed. This inertially fixed attitude satisfies the attitude requirements for the IMU realignment occurring approximately 9 minutes after the CSM enters darkness. About 7 minutes before the CSM enters sunlight, the inertial attitude hold is terminated. and the CSM is maneuvered to the initial landmark tracking attitude for a Mode III type landmark sighting sequence, which occurs early in the fifth revolution on the second control point landmark (Table IV). The initial landmark sighting attitude, which is a pitch of 5 degrees with respect to the local horizontal orientation, is held locally fixed through the completion of the fourth revolution.

This attitude sequence allows S-band communications from the completion of the landmark evaluation to the loss of MSFN line of sight.

5.5 Fifth Revolution (Figure 10)

The sequence of significant events that occur during the fifth revolution is as follows:

- 1. Landmark sighting on the second control point landmark
- 2. Acquisition of MSFN line of sight

- 3. Landmark sighting on the pseudo landing site landmark
- 4. Enter darkness
- 5. IMU realignment
- 6. Loss of MSFN line of sight
- 7. Enter sunlight

At the beginning of the fifth revolution, the CSM is in the locally fixed initial landmark tracking attitude. A Mode III type landmark sighting sequence is performed on the second control point landmark (Table IV), and then the vehicle is maneuvered back to the initial landmark tracking attitude for a Mode III type landmark sighting sequence on the pseudo landing site landmark. After the completion of the sighting sequence on the pseudo landing site landmark, the CSM is rolled 180 degrees to gain S-band communications, and the resulting attitude is held inertially fixed. This inertially fixed attitude satisfies the attitude requirements for the IMU realignment occurring approximately 15 minutes after the CSM enters darkness. About the time the CSM enters sunlight, the inertial attitude hold is terminated, and the CSM is maneuvered to the initial landmark tracking attitude for a Mode III type landmark sighting sequence, which occurs early in the sixth revolution on the second control point landmark. The landmark sighting attitude is held locally fixed through the completion of the fifth revolution.

This attitude sequence allows S-band communications from the completion of the landmark sighting sequence on the pseudo landing site landmark to the loss of MSFN line of sight.

5.6 Sixth Revolution (Figure 11)

The sequence of significant events that occur during the sixth revolution is as follows:

- 1. Landmark sighting on the second control point landmark
- 2. Acquisition of MSFN line of sight
- 3. Landmark sighting on the pseudo landing site landmark
- 4. Enter darkness
- 5. IMU realignment
- 6. Loss of MSFN line of sight
- 7. Enter sunlight
- 8. Landmark sighting on the first control point landmark

At the beginning of the sixth revolution, the CSM is in the locally fixed initial landmark tracking attitude. A Mode III type landmark sighting sequence is performed on the second control point landmark, and then the vehicle is maneuvered back to the locally fixed initial landmark tracking attitude for a Mode III type landmark sighting sequence on the pseudo landing site landmark. After the completion of the sighting sequence on the pseudo landing site landmark, the CSM is rolled 180 degrees to gain S-band communications, and the resulting attitude is held inertially fixed. This inertially fixed attitude satisfies the attitude requirements for the IMU realignment occurring approximately 13 minutes after the CSM enters darkness. About 5 minutes before the CSM enters sunlight, the inertial attitude hold is terminated, and the CSM is maneuvered to the initial landmark tracking attitude for a Mode III type landmark sighting sequence on the first control point landmark (Table IV). After the completion of the sighting sequence, the vehicle is maneuvered back to the locally fixed initial landmark tracking attitude for a Mode III type landmark sighting sequence, which occurs early in the seventh revolution on the second control point landmark. The inital landmark sighting attitude is held locally fixed through the completion of the sixth revolution.

This attitude sequence allows S-band communications from the completion of the landmark sighting sequence on the pseudo landing site landmark to the loss of MSFN line of sight.

5.7 Seventh Revolution (Figure 12)

The sequence of significant events that occur during the seventh revolution is as follows:

- 1. Landmark sighting on the second control point landmark
- 2. Acquisition of MSFN line of sight
- 3. Landmark sighting on the third control point landmark
- 4. Landmark sighting on the pseudo landing site landmark
- 5. Enter darkness
- 6. IMU realignment
- 7. Loss of MSFN line of sight
- 8. Enter sunlight
- 9. Landmark sighting on the first control point landmark

At the beginning of the seventh revolution, the CSM is in the locally fixed initial landmark tracking attitude. A Mode III type landmark sighting sequence is performed on the second control point landmark, and then the vehicle is maneuvered back to the locally fixed initial landmark tracking attitude for a Mode III type landmark sighting sequence on the third

control point landmark (Table IV). Upon completion of the sighting on the third control point landmark, the CSM is maneuvered back to the locally fixed initial landmark tracking attitude for a Mode III type landmark sighting sequence on the pseudo landing site landmark. After the completion of the sighting sequence on the pseudo landing site landmark, the CSM is rolled 180 degrees to gain S-band communications, and the resulting attitude is held inertially fixed. This inertially fixed attitude satisfies the attitude requirements for the IMU realignment occurring approximately 13 minutes after the CSM enters darkness. About 3 minutes before the CSM enters sunlight, the inertial attitude hold is terminated, and the CSM is maneuvered to the initial landmark tracking attitude for a Mode III type landmark sighting sequence on the first control point landmark. After the completion of the sighting sequence, the vehicle is maneuvered back to the locally fixed initial landmark tracking attitude for a Mode III type landmark sighting sequence, which occurs early in the eighth revolution on the second control point landmark. The initial landmark sighting attitude is held locally fixed through the completion of the seventh revolution.

This attitude sequence allows S-band communications from the completion of the landmark sighting sequence on the pseudo landing site landmark to the loss of MSFN line of sight.

5.8 Eighth Revolution (Figure 13)

The sequence of significant events that occur during the eighth revolution is as follows:

- 1. Landmark sighting on the second control point landmark
- 2. Acquisition of MSFN line of sight
- 3. Landmark sighting on the third control point landmark
- 4. Landmark sighting on the pseudo landing site landmark
- 5. Enter darkness
- 6. IMU realignment
- 7. Dark side and solar corona photography
- 8. Loss of MSFN line of sight
- 9. Orbital navigation photography (convergent stereo photography)
- 10. Enter sunlight

At the beginning of the eighth revolution, the CSM is in the locally fixed initial landmark tracking attitude. A Mode III type landmark sighting sequence is performed on the second control point landmark, and then the vehicle is maneuvered back to the locally fixed initial landmark tracking attitude for a Mode III type landmark sighting sequence on the third

control point landmark. Upon completion of the sighting on the third control point landmark, the CSM is maneuvered back to the locally fixed initial landmark tracking attitude for a Mode III type landmark sighting sequence on the pseudo landing site landmark. After the completion of the sighting sequence on the pseudo landing site landmark, the CSM is rolled 180 degrees to gain S-band communications, and the resulting attitude is held inertially fixed. This inertially fixed attitude satisfies the attitude requirements for the IMU realignment occurring approximately 9 minutes after the CSM enters darkness. Seventeen minutes before the CSM enters sunlight, the inertial attitude hold is terminated, and the CSM is maneuvered to an attitude which allows dark side and solar corona photography. The vehicle attitude, with respect to the local horizontal orientation, is a pitch of minus 20 degrees and a roll of 180 degrees. This attitude is held locally fixed for 15 minutes. The CSM is then maneuvered to an attitude which allows orbital navigation photography. This vehicle attitude, with respect to the local horizontal orientation, is a pitch of minus 70 degrees and a roll of 180 degrees. The attitude is held locally fixed through the completion of the eighth revolution.

This attitude sequence allows S-band communications from the completion of the landmark sighting sequence on the pseudo landing site landmark to the maneuver to the dark side and solar corona photography attitude.

5.9 Ninth Revolution (Figure 14)

The sequence of significant events that occur during the ninth revolution is as follows:

- 1. Orbital navigation photography (convergent stereo photography)
- 2. Acquisition of MSFN line of sight
- 3. Enter darkness
- 4. IMU realignment
- 5. Loss of MSFN line of sight
- 6. Enter sunlight

At the start of the ninth revolution, the CSM is in the orbital navigation photography attitude. This attitude is held locally fixed until the CSM passes over the subsolar point. The CSM is then pitched 40 degrees and rolled 180 degrees, and the resulting attitude is held locally fixed while the convergent stereo photography continues. Approximately one minute after the CSM enters darkness, the local attitude hold is terminated, and the CSM is rolled 180 degrees and pitched minus 57.5 degrees. The resulting attitude is then held inertially fixed. This inertially fixed attitude satisfies the attitude requirements for the IMU realignment occurring approximately 15 minutes after the CSM enters darkness. At the loss of MSFN line of sight, the inertial attitude hold is terminated, and

the CSM is maneuvered to a lunar observation attitude. The vehicle attitude, with respect to the local horizontal orientation, is a pitch of minus 45 degrees and a roll of 180 degrees. This attitude is held locally fixed through the completion of the ninth revolution.

This attitude sequence allows S-band communications from 11 minutes prior to the termination of orbital navigation photography to the loss of MSFN line of sight.

5.10 Tenth Revolution (Figure 15)

The sequence of significant events that occur during the tenth revolution is as follows:

- 1. Acquisition of MSFN line of sight
- 2. Enter darkness
- 3. IMU realignment
- 4. Loss of MSFN line of sight
- 5. Enter sunlight
- 6. Transearth injection (TEI) burn

At the start of the tenth revolution, the CSM is in the locally fixed lunar observation attitude. Approximately 20 minutes before the CSM enters darkness, the local attitude hold is terminated, and the existing attitude is held inertially fixed. This inertially fixed attitude satisfies the attitude requirements for the IMU realignment beginning as the CSM enters darkness. Approximately 9 minutes before the CSM enters sunlight, the inertial attitude hold is terminated, and the vehicle is maneuvered to the TEI burn attitude. The burn attitude is then held inertially fixed through the burn. The TEI burn boosts the CSM from the 60-nautical mile circular lunar orbit into the transearth trajectory. The burn is performed with the CSM in a posigrade attitude, and the crew is heads down to afford visual reference with the lunar surface.

This attitude sequence allows S-band communications from acquisition of MSFN line of sight to loss of MSFN line of sight.

6. TRANSEARTH PHASE

Spacecraft look angles and IMU gimbal angles for the major events during the transearth phase of the mission are given in Table II(d).

6.1 Post-TEI Sequence of Events

Cutoff of the TEI burn occurs at 89:06:53 g.e.t. Following the burn termination, the CSM X-axis is positioned along the negative moon radius vector with the Z-axis in the direction of motion and in the plane of the trajectory. This orientation provides the crew with visual observation of the moon and is also acceptable for S-band/MSFN communications when earth line of sight is acquired.

Approximately one hour after TEI, the IMU will be realigned, and star/lunar landmark navigation sightings will be performed. The CSM will then be oriented for the first transearth PTC period.

6.2 Passive Thermal Control Tumble Mode

A type of PTC designated as the PTC tumble mode was simulated for the first transearth PTC period of approximately 5 hours. This mode has been included in the timeline to obtain thermal and stability characteristics of the spacecraft while in this attitude mode.

The initial PTC tumble mode orientation is as follows. The CSM X-axis is pointed towards the sun and the CSM Z-axis is 45 degrees below the trajectory plane pointing in the general direction of the earth. With this initial attitude a yaw rate of two revolutions per hour is then induced which turns the X-axis through 360 degrees with respect to the sun. The CSM attitude chosen for the tumble mode simulation in this timeline has been derived by considering S-band communications and gimbal lock avoidance requirements. The PTC tumble mode orientation with the appropriate earth-moon-sun geometry is shown in Figure 16.

6.3 Pre-Entry Sequence of Events

Prior to the time set for the final TE MCC, the IMU will be aligned to the entry REFSMMAT. Attitude maneuvers after this event thus will reflect the change in alignment of the IMU. Following the last MCC time, the crew performs an IMU realignment. This alignment is performed in the entry attitude which is a pitch maneuver of 156 degrees from the entry REFSMMAT alignment of 0, 0, 0 (roll, pitch, yaw) gimbal angles. This maneuver results in a heads-down retrograde attitude held inertially fixed until approximately 17 minutes prior to entry. At this time, the space-craft orients to the CM/SM separation attitude with the X-axis in a

retrograde position 32 degrees below the local horizontal. The space-craft is yawed positively through 45 degrees, and the crew is heads down. After separation, at entry minus 15 minutes, the CM returns to the entry attitude. The CM/SM separation and spacecraft entry attitude are shown in Figures 17a and 17b, respectively.

Table I. C-prime Lunar Orbit Mission Event Sequence

| Mission Time (hr:min:sec) | Event |
|---------------------------|--|
| 1 | |
| | Earth Orbit |
| 00:11:20 | Earth orbit insertion, inertial attitude hold |
| 00:11:35 | Orient S-IVB/CSM to + X-axis forward, heads down, Z-axis inplane, initiate local attitude hold |
| 02:50:31 | Initiate TLI burn |
| | Translunar |
| 02:55:43 | TLI cutoff, inertial attitude hold |
| 02:56:03 | Orient S-IVB/CSM to + X-axis forward, heads down, Z-axis inplane, initiate local attitude hold |
| 03:10:43 | Orient to S-IVB/CSM separation attitude, inertial attitude hold |
| 03:20:43 | S-IVB/CSM separation, inertial attitude hold |
| 03:21:43 | Execute 180-deg pitch at 5 deg/sec |
| 03:22:23 | Execute negative 60-deg roll, begin station keeping |
| 03:35:43 | Orient to evasive maneuver attitude |
| 05:07:43 | Orient to optical monitoring of S-IVB attitude |
| 06:00:00 | Orient to navigation sighting attitude |
| 06:10:00 | Perform star/earth horizon navigation sightings |
| 07:00:00 | Complete navigation sightings and initiate 45-deg roll to IMU alignment attitude |
| 07:10:00 | Perform IMU fine alignment |
| 07:30:00 | Complete IMU fine alignment and roll 180 deg |
| 08:00:00 | Orient to IMU alignment attitude |
| 08:10:00 | Perform IMU fine alignment |
| 08:30:00 | Complete IMU alignment |
| 09:00:00 | Initiate spacecraft midcourse correction |
| 09:10:00 | Orient to navigation sighting attitude |
| 09:20:00 | Perform star/earth landmark navigation sightings |
| 09:50:00 | Complete navigation sightings and orient for PTC |
| 10:05:00 | Establish pitch-yaw hold; initiate 0. 2-deg/sec roll rate |
| 15:50:00 | Complete PTC and orient to navigation sighting attitude |

Table I. C-prime Lunar Orbit Mission Event Sequence (Continued)

| Mission Time | Tiront |
|--------------|---|
| (hr:min:sec) | \underline{Event} |
| | Translunar (Continued) |
| 16:00:00 | Perform star/earth horizon navigation sightings |
| 16:50:00 | Complete navigation sighting and orient for PTC |
| 17:05:00 | Establish pitch-yaw hold, initiate 0.2-deg/sec roll rate |
| 26:20:00 | Complete PTC and orient to navigation sighting attitude |
| 26:30:00 | Perform star/earth horizon navigation sightings |
| 27:00:00 | Complete navigation sightings and orient to IMU align- ment attitude |
| 27:10:00 | Perform IMU alignment |
| 27:30:00 | Complete IMU alignment |
| 28:00:00 | Initiate spacecraft midcourse correction |
| 28:10:00 | Orient to navigation sighting attitude |
| 28:20:00 | Perform star/earth horizon navigation sightings |
| 29:00:00 | Complete navigation sighting and orient for PTC |
| 29:15:00 | Establish pitch-yaw hold, initiate 0.2-deg/sec roll rate |
| 34:10:00 | Complete PTC and orient to navigation sighting attitude |
| 34:20:00 | Perform star/earth horizon navigation sightings |
| 34:50:00 | Complete navigation sighting and orient for PTC |
| 35:05:00 | Establish pitch-yaw hold, initiate 0.2-deg/sec roll rate |
| 45:00:00 | Complete PTC and orient to navigation sighting attitude |
| 45:10:00 | Perform star/lunar horizon navigation sightings |
| 46:00:00 | Complete navigation sighting and orient to IMU align- ment attitude |
| 46:10:00 | Perform IMU alignment |
| 46:30:00 | Complete IMU alignment |
| 47:00:00 | Initiate spacecraft midcourse correction |
| 47:10:00 | Orient to navigation sighting attitude |
| 47:20:00 | Perform star/earth horizon navigation sightings |
| 47:50:00 | Complete navigation sighting and orient for PTC |
| 48:05:00 | Establish pitch-yaw hold, initiate 0.2-deg/sec roll rate |
| 56:50:00 | Complete PTC and orient to navigation sighting attitude |
| 57:00:00 | Perform star/lunar horizon navigation sightings |

Table I. C-prime Lunar Orbit Mission Event Sequence (Continued)

| Mission Time (hr:min:sec) | Event |
|---------------------------|---|
| | Translunar (Continued) |
| 57:50:00 | Complete navigation sightings and orient for PTC |
| 58:05:00 | Establish pitch-yaw hold, initiate 0. 2-deg/sec roll rate |
| 60:05:00 | Complete PTC and orient to IMU alignment attitude |
| 60:15:00 | Perform IMU alignment |
| 60:30:00 | Complete IMU alignment |
| 61:00:00 | Initiate spacecraft midcourse correction |
| 61:15:00 | Orient for PTC |
| 61:30:00 | Establish pitch-yaw hold, initiate 0. 2-deg/sec roll rate |
| 65:50:00 | Complete PTC and orient to IMU alignment attitude |
| 66:00:00 | Perform IMU alignment |
| 66:20:00 | Complete IMU alignment and orient for PTC |
| 66:35:00 | Establish pitch-yaw hold, initiate 0. 2-deg/sec roll rate |
| 68:05:00 | Complete PTC and orient to IMU alignment attitude |
| 68:15:00 | Perform IMU alignment |
| 68:35:00 | Complete IMU alignment |
| 69:07:29 | Initiate LOI-1 burn |
| | Lunar Orbit |
| 69:11:35 | LOI-1 cutoff, inertial attitude hold |
| 69:29:00 | Roll 180 deg for communications, inertial attitude hold |
| 69:30:20 | Acquire Honeysuckle Creek signal |
| 70:14:12 | Enter lunar umbra, begin IMU realignment |
| 70:36:35 | Acquire Madrid signal |
| 70:54:58 | Lose Madrid signal |
| 70:55:13 | Lose Honeysuckle Creek signal, maneuver to lunar observation and photography attitude, local attitude hol |
| 71:00:26 | Enter sunlight |
| 71:38:25 | Acquire Madrid signal |
| 71:38:35 | Acquire Honeysuckle Creek signal |
| 72:08:30 | Lose Honeysuckle Creek signal |

Table I. C-prime Lunar Orbit Mission Event Sequence (Continued)

| Mission Time (hr:min:sec) | Event |
|---------------------------|---|
| | Lunar Orbit (Continued) |
| 72:15:00 | Terminate local attitude hold and begin inertial attitude hold |
| 72:22:47 | Enter lunar umbra |
| 72:27:00 | Begin IMU realignment |
| 72:55:00 | Maneuver to circularization burn attitude except rolled 180-deg, inertial attitude hold |
| 73:03:18 | Lose Madrid signal |
| 73:05:00 | Roll 180 deg to circularization burn attitude, inertial attitude hold |
| 73:09:01 | Enter sunlight |
| 73:30:53 | Initiate circularization burn |
| 73:31:03 | Circularization burn cutoff, inertial attitude hold |
| 73:40:00 | Maneuver to landmark training photography attitude, local attitude hold |
| 73:47:48 | Acquire Madrid signal |
| 74:14:16 | Start manual pitch rate for landmark training photograph |
| 74:16:33 | Terminate pitch rate, pitch up for IMU realignment, inertial attitude hold |
| 74:22:53 | Enter lunar umbra |
| 74:30:00 | Begin IMU realignment |
| 74:55:00 | Maneuver to orbital navigation photography attitude, local attitude hold |
| 74:59:49 | Lose Madrid signal |
| 75:09:00 | Enter sunlight |
| 75:44:00 | Roll 180 deg, continue orbital navigation photography, local attitude hold |
| 75:46:11 | Acquire Madrid signal |
| 76:00:00 | Maneuver to landmark evaluation attitude, local attitude hold |
| 76:10:20 | Start -0.3 deg/sec pitch rate for landmark evaluation |
| 76:14:49 | Terminate pitch rate, roll 180 deg, inertial attitude hold |
| 76:21:29 | Enter lunar umbra |
| 76:30:00 | Begin IMU realignment |
| 76:58:10 | Lose Madrid signal |

Table I. C-prime Lunar Orbit Mission Event Sequence (Continued)

| Mission Time (hr:min:sec) | Event |
|---------------------------|---|
| | Lunar Orbit (Continued) |
| 77:00:00 | Maneuver to landmark sighting attitude, local attitude hold |
| 77:07:35 | Enter sunlight |
| 77:30:19 | Start -0.3 deg/sec pitch rate for second control point landmark sighting |
| 77:34:48 | Terminate pitch rate, maneuver to landmark sighting attitude, local attitude hold |
| 77:44:32 | Acquire Madrid signal |
| 78:08:09 | Acquire Goldstone signal |
| 78:08:36 | Start -0.3 deg/sec pitch rate for pseudo landing site sighting |
| 78:13:05 | Terminate pitch rate, roll 180 deg, inertial attitude hold |
| 78:20:05 | Enter lunar umbra |
| 78:35:00 | Begin IMU realignment |
| 78:56:11 | Lose Goldstone signal |
| 78:56:32 | Lose Madrid signal |
| 79:06:00 | Maneuver to landmark sighting attitude, local attitude hold |
| 79:06:12 | Enter sunlight |
| 79:28:3 | Start -0.3 deg/sec pitch rate for second control point landmark sighting |
| 79:33:05 | Terminate pitch rate, maneuver to landmark sighting attitude, local attitude hold |
| 79:42:30 | Acquire Goldstone signal |
| 79:42:51 | Acquire Madrid signal |
| 80:06:52 | Start -0.3 deg/sec pitch rate for pseudo landing site sighting |
| 80:11:21 | Terminate pitch rate, roll 180 deg, inertial attitude hold |
| 80:18:41 | Enter lunar umbra |
| 80:32:00 | Begin IMU realignment |
| 80:54:28 | Lose Goldstone signal |
| 80:54:50 | Lose Madrid signal |

Table I. C-prime Lunar Orbit Mission Event Sequence (Continued)

| Mission Time (hr:min:sec) | Event | |
|---------------------------|---|--|
| | Lunar Orbit (Continued) | |
| 81:00:00 | Maneuver to landmark sighting attitude, local attitude hold | |
| 81:04:48 | Enter sunlight | |
| 81:12:25 | Start -0.3 deg/sec pitch rate for first control point landmark sighting | |
| 81:16:54 | Terminate pitch rate, maneuver to landmark sighting attitude, local attitude hold | |
| 81:26:53 | Start -0.3 deg/sec pitch rate for second control point landmark sighting | |
| 81:31:22 | Terminate pitch rate, maneuver to landmark sighting attitude, local attitude hold | |
| 81:40:51 | Acquire Goldstone signal | |
| 81:44:48 | Start -0.3 deg/sec pitch rate for third control point landmark sighting | |
| 81:49:17 | Terminate pitch rate, maneuver to landmark sighting attitude, local attitude hold | |
| 82:05:08 | Start -0.3 deg/sec pitch rate for pseudo landing site sighting | |
| 82:09:37 | Terminate pitch rate, roll 180 deg, inertial attitude hol | |
| 82:17:17 | Enter lunar umbra | |
| 82:30:00 | Begin IMU realignment | |
| 82:52:49 | Lose Goldstone signal | |
| 83:00:00 | Maneuver to landmark sighting attitude, local attitude hold | |
| 83:03:24 | Enter sunlight | |
| 83:10:42 | Start -0.3 deg/sec pitch rate for first control point landmark sighting | |
| 83:15:11 | Terminate pitch rate, maneuver to landmark sighting attitude, local attitude hold | |
| 83:25:09 | Start -0.3 deg/sec pitch rate for second control point landmark sighting | |
| 83:29:38 | Terminate pitch rate, maneuver to landmark sighting attitude, local attitude hold | |
| 83:39:13 | Acquire Goldstone signal | |
| 83:43:05 | Start -0.3 deg/sec pitch rate for third control point landmark sighting | |

Table I. C-prime Lunar Orbit Mission Event Sequence (Continued)

| Mission Time (hr:min:sec) | Event |
|---------------------------|---|
| | Lunar Orbit (Continued) |
| 83:45:31 | Acquire Honeysuckle Creek signal |
| 83:47:34 | Terminate pitch rate, maneuver to landmark sighting attitude, local attitude hold |
| 84:03:24 | Start -0.3 deg/sec pitch rate for pseudo landing site sighting |
| 84:07:53 | Terminate pitch rate, roll 180 deg, inertial attitude hold |
| 84:15:54 | Enter lunar umbra |
| 84:25:00 | Begin IMU realignment |
| 84:45:00 | Maneuver to darkside and solar corona photography attitude, local attitude hold |
| 84:50:47 | Lose Honeysuckle Creek signal |
| 84:51:14 | Lose Goldstone signal |
| 85:00:00 | Maneuver to orbital navigation photography attitude, local attitude hold |
| 85:02:00 | Enter sunlight |
| 85:37:00 | Pitch 40 deg, roll 180 deg and continue orbital navigation photography, local attitude hold |
| 85:37:06 | Acquire Honeysuckle Creek signal |
| 85:37:35 | Acquire Goldstone signal |
| 86:14:30 | Enter lunar umbra |
| 86:16:00 | Roll 180 deg, pitch up for IMU realignment, inertial attitude hold |
| 86:30:00 | Begin IMU realignment |
| 86:49:05 | Lose Honeysuckle Creek signal |
| 86:49:35 | Lose Goldstone signal |
| 86:50:00 | Maneuver to lunar observation attitude, local attitude hold |
| 87:00:37 | Enter sunlight |
| 87:35:27 | Acquire Honeysuckle Creek signal |
| 87:35:54 | Acquire Goldstone signal |
| 87:53:00 | Terminate local attitude hold, start inertial attitude hold |
| 88:13:05 | Enter lunar umbra, begin IMU realignment |
| 88:47:25 | Lose Honeysuckle Creek signal |

Table I. C-prime Lunar Orbit Mission Event Sequence (Continued)

| Mission Time (hr:min:sec) | Event |
|---------------------------|---|
| | Lunar Orbit (Continued) |
| 88:47:53 | Lose Goldstone signal |
| 88:50:00 | Maneuver to TEI burn attitude, inertial attitude hold |
| 88:59:12 | Enter sunlight |
| 89:04:02 | Initiate TEI burn |
| | Transearth |
| 89:06:53 | TEI cutoff, orient to vertical (+ X down, + Z, forward), inertial attitude hold |
| 90:00:00 | Orient to IMU alignment attitude |
| 90:10:00 | Perform IMU alignment |
| 90:30:00 | Complete IMU alignment and orient to navigation sight-ing attitude |
| 90:40:00 | Perform star/lunar landmark navigation sightings |
| 92:00:00 | Complete navigation sighting and orient for PTC tumble mode |
| 92:15:00 | Establish pitch-roll hold, initiate 0. 2-deg/sec yaw rate |
| 97:10:00 | Complete PTC and orient to navigation sighting attitude |
| 97:20:00 | Perform star/lunar horizon navigation sightings |
| 98:00:00 | Complete navigation sighting and orient to IMU alignmen attitude |
| 98:10:00 | Perform IMU alignment |
| 98:30:00 | Complete IMU alignment |
| 99:00:00 | Initiate spacecraft midcourse correction |
| 99:10:00 | Orient for navigation sighting attitude |
| 99:20:00 | Perform star/earth horizon navigation sightings |
| 99:50:00 | Complete navigation sighting and orient for PTC |
| 100:05:00 | Establish pitch-yaw hold, initiate 0.2-deg/sec roll rate |
| 106:10:00 | Complete PTC and orient to navigation sighting attitude |
| 106:20:00 | Perform star/lunar horizon navigation sightings |
| 106:50:00 | Complete navigation sighting and orient for PTC |
| 107:05:00 | Establish pitch-yaw hold, initiate 0. 2-deg/sec roll rate |
| | |

Table I. C-prime Lunar Orbit Mission Event Sequence (Continued)

| Mission Time (hr:min:sec) | Event |
|---------------------------|--|
| | Transearth (Continued) |
| 116:00:00 | Complete PTC and orient for navigation sightings |
| 116:10:00 | Perform star/lunar horizon navigation sightings |
| 117:00:00 | Complete navigation sighting and orient to IMU alignment attitude |
| 117:10:00 | Perform IMU alignment |
| 117:30:00 | Complete IMU alignment |
| 118:00:00 | Initiate spacecraft midcourse correction |
| 118:10:00 | Orient to navigation sighting attitude |
| 118:20:00 | Perform star/earth horizon navigation sightings |
| 118:50:00 | Complete navigation sighting and orient for PTC |
| 119:05:00 | Establish pitch-yaw hold, initiate 0. 2-deg/sec roll rate |
| 128:50:00 | Complete PTC and orient for navigation sightings |
| 129:00:00 | Perform star/earth horizon navigation sightings |
| 129:30:00 | Complete earth navigation sighting and orient for lunar navigation sightings |
| 129:40:00 | Perform star/lunar horizon navigation sightings |
| 130:10:00 | Complete navigation sighting and orient for PTC |
| 130:25:00 | Establish pitch-yaw hold, initiate 0. 2-deg/sec roll rate |
| 140:00:00 | Complete PTC and orient to navigation sighting attitude |
| 140:10:00 | Perform star/lunar horizon navigation sightings |
| 141:00:00 | Complete navigation sighting and orient to IMU alignment attitude |
| 141:10:00 | Perform IMU alignment |
| 141:30:00 | Complete IMU alignment |
| 142:00:00 | Initiate spacecraft midcourse correction |
| 142:10:00 | Orient to navigation sighting attitude |
| 142:20:00 | Perform star/earth horizon navigation sightings |
| 142:50:00 | Complete navigation sighting and orient for PTC |
| 143:05:00 | Establish pitch-yaw hold, initiate 0. 2-deg/sec roll rate |
| 148:50:00 | Complete PTC and orient to navigation sighting attitude |
| 149:00:00 | Perform star/earth horizon navigation sightings |

Table I. C-prime Lunar Orbit Mission Event Sequence (Continued)

| Mission Time (hr:min:sec) | Event |
|---------------------------|---|
| | Transearth (Continued) |
| 149:50:00 | Complete navigation sighting and orient for PTC |
| 150:05:00 | Establish pitch-yaw hold, initiate 0.2-deg/sec roll rate |
| 155:50:00 | Complete PTC and orient to navigation sighting attitude |
| 156:00:00 | Perform star/earth horizon navigation sightings |
| 156:30:00 | Reorient and perform star/lunar landmark navigation sightings |
| 157:00:00 | Complete navigation sighting and orient for PTC |
| 157:15:00 | Establish pitch-yaw hold, initiate 0.2 deg/sec roll rate |
| 167:30:00 | Complete PTC and orient to IMU orientation determination |
| 168:00:00 | Complete IMU orientation determination and orient to IMU alignment attitude |
| 168:10:00 | Perform IMU alignment |
| 168:30:00 | Complete IMU alignment |
| 169:05:00 | Initiate spacecraft midcourse correction |
| 170:00:00 | Perform IMU alignment |
| 170:20:00 | Complete IMU alignment |
| 170:48:32 | Orient to separation attitude |
| 170:50:32 | CM/SM separation |
| 171:05:32 | Entry |

Table II. Spacecraft Attitude Data (a) Earth Orbit

| | | ć | oranhic Do | ونزنوه | Local | Local Horizontal | ntal | i IIVII | A ladani | 20100 | |
|------------------------------|------------------------------|-----------|------------|---|----------------------------|------------------|---------------|-------------------------|--------------|-------------------|---|
| Mission Time (hr:min:sec) | Event | Attitude* | Latitude* | Attitude* Latitude* Longitude* (n mi) (deg) (deg) | Pitch Yaw Roll (deg) (deg) | Yaw (deg) | Roll (deg) | IGA MGA OGA (deg) (deg) | MGA (deg) | OGA (deg) | Comments |
| 00:11:50 | Earth orbit insertion | 103.3 | 32.5 | -54.3 | 0.0 | 0.0 0.0 180.0 | 180.0 | -115.3 | 9.0 | -179.2 | -115.3 0.6 -179.2 Inertial hold |
| 00:11:35 | Begin local attitude hold | 103.3 | 32.5 | -52.8 | 0.0 | 0.0 0.0 180.0 | 180.0 | -115.3 | 9.0 | -115.3 0.6 -179.2 | |
| 02:50;31 | Initiate TLI burn | 99.5 | 9.5 | -165.9 | 0.0 | 0.0 180.0 | 180.0 | -45.8 | 1.1 | 179.3 | -45.8 1.1 179.3 Terminate local attitude hold |

* Altitude is measured with respect to the Fischer reference ellipsoid; latitude and longitude are measured positive north of the equator and east from the Greenwich meridian, respectively.

Table II. Spacecraft Attitude Data (b) Translunar

| | | , | | | 2 | DAIL Gimbal | | Look Angles | 8010 | Look Angles | ngles | Look A | ngles | |
|--------------|--|----------------|---------------------|---------------|--------------|--------------|--------|----------------|--------|-------------|---------|--------|--------|---------------------------------------|
| | | 2005 | Geocentric Inertial | | | Angles | | to Earth | rth | to M | to Moon | to Sun | - E | |
| Mission Time | (d) | Pitch (deg) | Yaw (deg) | Roll (deg) | IGA (deg) | MGA (deg) | (dek) | Theta (deg) | deg) | (deg) | (deg) | (deg) | de g | Comments |
| (nr:min:sec) | | 1 | 7 44 | , | -70.5 | 6.5 | -179.8 | 90.06 | 0.0 | 50.3 | - 44.0 | 45.7 | -81.8 | Inertial hold at cutoff not simulated |
| 2:55:43 | TLI cutoff | 1.60- | 1,66 | 0 00 1 1/1 | -70.5 | 3.9 | -179.8 | 0.06 | 0.0 | 50,3 | -44.0 | 45.7 | -81.8 | Inertial hold |
| 5:56:03 | begin local attitude noto | | 36.0 | - 60 2 | 8 | 2.6 | 177.1 | 160.0 | 180.0 | 93.0 | -32.9 | 69.3 | -49.2 | Begin inertial hold |
| 3:10:43 | S-IVB/CSM orient to separation attitude | 141.0 | -36.9 | -60.2 | -18.8 | 7.6 | 177,1 | 140.5 | 180.0 | 93, 3 | -33,3 | 69.3 | -49.2 | Separation distance ~ 50 ft |
| 3:20:43 | Sat Value acpairation | 39.0 | 36.9 | 60.2 | 161.2 | -2.6 | -177.1 | 39,5 | 0.0 | 86.7 | -146.7 | 110.7 | -130.8 | 5 deg/sec maneuver rate |
| 3:21:43 | Fitch 100 deg | 39.0 | 36.9 | 0.2 | 161.2 | -2.6 | 122.9 | 40.4 | 60.0 | 86.7 | -86.7 | 110.7 | -70.8 | 5 deg/sec maneuver rate |
| 3:22:23 | Koli negative ou deg | 4004 | 7 99 | 170.3 | 107.7 | -3.9 | -0.3 | 0.0 | -0.8 | 129.1 | 45.5 | 134.5 | 83.4 | Begin inertial hold |
| 5:35:43 | | 160 4 | 7.0 | -104.8 | 0.69 | -14.0 | 139.8 | 14.9 | -94.4 | 155.6 | - 58.2 | 136.8 | -20.0 | Begin inertial hold |
| 5:07:43 | Opione for navigation aighting | -169.4 | 4 7.9 | -104.8 | 69.0 | -14.0 | 139.8 | 11.9 | -73.3 | 154.8 | -57.8 | 136.8 | -20.0 | Continue inertial hold |
| 00:00:0 | distribution of the factor and the factor of | 86.4 | 58.9 | -156.3 | 124.0 | 1.6 | 2.9 | 51,3 | -177.7 | 112.2 | 41.0 | 125.5 | 68.1 | Begin inertial hold |
| 00:00:0 | | 86.4 | 58.9 | -156.3 | 124.0 | 1.6 | 5.9 | 54.6 | -178.2 | 112.0 | 41.7 | 125, 5 | 0.89 | Begin roll 45 deg for IMU attitude |
| 1:40:00 | Dange of the distance of | 86.4 | . 85 | -111.3 | 124.0 | 1.6 | 47.9 | 55.2 | 136.7 | 112.0 | -3.2 | 125.5 | 23.0 | Continue inertial hold |
| 00:00:1 | Centrality Dell aliment | 86.4 | 58.9 | -111.3 | 124.0 | 1.6 | 47.9 | 56.2 | 136.6 | 112.0 | -3,0 | 125.5 | 23.0 | Begin roll 180 deg |
| 00:00:0 | Complete De Caragoniani | 4.6 | 58.9 | 68.7 | 124.0 | 1.6 | -132,1 | 57.6 | -43.6 | 111.9 | 177.4 | 125.5 | -157.0 | 0.5 deg/sec maneuver rate |
| 00:00:0 | Description of the second | 86.4 | 58.9 | 68.7 | 124.0 | 1.6 | -132.1 | 58.0 | -43.7 | 111.9 | 177.5 | 125.5 | -157.0 | Continue inertial hold |
| 00:00:0 | Complete DMI slignment | 86.4 | 58.9 | 68.7 | 124.0 | 1.6 | -132,1 | 58,8 | -43.8 | 111.8 | 177.8 | 125.5 | -157.0 | Continue inertial hold |
| 9:30:00 | Taitiete mideourse correction | 86.4 | 58.9 | 68,7 | 124.0 | 1.6 | -132.1 | 59.9 | -43.9 | 111.8 | 178.1 | 125, 5 | -157,1 | Continue inertial hold |
| 00:00:0 | Onione for particularity and things | 86.4 | 58.9 | 68,7 | 124.0 | 1.6 | -132,1 | 60.2 | -43.9 | 111.8 | 178.2 | 125.5 | -157.1 | 0.5 deg/sec maneuver rate |
| 9:10:00 | Desform SEL navigation sightings | 179.7 | -19.9 | -90.8 | 12.2 | 26.5 | 157.8 | 57.5 | 180.0 | 96.4 | -30,6 | 71.8 | -24.0 | Begin inertial hold |
| 00.03.6 | Complete navigation sightings: orient for PTC | 179.7 | -19.9 | 8.06- | 12.2 | 26, 5 | 157.8 | 56.7 | 179,5 | 96.1 | -30.8 | 71.8 | -23.9 | 0.5 deg/sec maneuver rate |
| 00:00:00 | | -106.5 | -22.6 | -40, 1 | -29.1 | -28.8 | 177.1 | 90.0 | 180.0 | 105.7 | -36.4 | 90.0 | -56.3 | Roll at 0, 2 deg/sec |
| 10:03:00 | Consists DTC: orient for navigation sightings | -106.5 | -22,6 | 139.9 | -29.1 | -28.8 | -2.9 | 84.8 | 3,3 | 105.9 | 140.8 | 90.0 | 123.9 | 0.5 deg/sec maneuver rate |
| 15:50:00 | Destant SEH navieation nightings | 111.8 | 44.7 | -164.7 | 110.7 | 18.0 | 16.9 | 57.5 | 177.8 | 105.8 | 41.8 | 112.6 | 65.1 | Begin inertial hold |
| 00:00:91 | Complete navigation sightings: orient for PIC | 111.8 | 4.7 | -164.7 | 110.7 | 18.0 | 16.9 | 58.0 | 177.5 | 105.7 | 42.1 | 112.6 | 65.1 | Continue inertial hold |
| 12:06:00 | CLO Tes | -99.1 | -23.2 | -33.3 | -36,1 | -32.1 | 177.5 | 90.0 | 180.0 | 103.9 | -41.9 | 90.0 | -60.0 | Roll at 0.2 deg/sec |
| 26.20.00 | Complete PTC: orient for navigation sightings | -99.1 | -23.2 | 146.7 | -36.1 | -32.1 | -2.5 | 86.4 | 2, 5 | 104.2 | 135.2 | 90.0 | 120.4 | 0.5 deg/sec maneuver rate |
| 26:30:00 | Derform SFH navigation sightings | 118.0 | 43, 5 | -172.9 | 105.9 | 18.8 | 14.5 | 58.0 | -179.7 | 105.9 | 50.2 | 112.4 | 70.5 | Begin inertial hold |
| 27:00:00 | Complete navigation sightings; begin | 118.0 | 43,5 | -172.9 | 105.9 | 18.8 | 14.5 | 58.1 | -179.8 | 105.9 | 50.3 | 112.4 | 70,5 | 0.5 deg/sec maneuver rate |
| 33.40.00 | Description DAM alignment | 118.0 | 43.5 | -172.9 | 105.9 | 18.8 | 14.5 | 58,2 | -179.8 | 105.8 | 50,3 | 112.4 | 70, 5 | Continue inertial hold |
| 27:10:00 | Complete DMI alignment | 118.0 | 43,5 | -172.9 | 105.9 | 18.8 | 14,5 | 58,3 | -179.9 | 105.8 | 50.4 | 112.4 | 70,5 | Continue inertial hold |
| 00:00:00 | Taiting mideouses correction | 118.0 | 43.5 | -172.9 | 105.9 | 18.8 | 14.5 | 58.4 | 180.0 | 105.8 | 50.5 | 112.5 | 70,5 | Continue inertial hold |
| 90:00:02 | Onited for newlantion sightings | 118.0 | 43.5 | -172.9 | 105.9 | 18.8 | 14.5 | 58.4 | 180.0 | 105.7 | 9.09 | 112.5 | 70.5 | 0.5 deg/sec maneuver rate |
| 00:01:07 | Danger Off part setting at shings | 120.4 | 4.0 | -174.2 | 104.1 | 18.1 | 15.5 | 56.7 | 179.3 | 107.1 | 50,5 | 113, 3 | 70.7 | Begin inertial hold |
| 00:07:87 | regions obtained assumed a property of DTC | 120.4 | 44.0 | -174.2 | 104.1 | 18.1 | 15,5 | 56.9 | 179.2 | 107.0 | 50,7 | 113.3 | 70,7 | 0.5 deg/sec maneuver rate |
| 00:00:67 | Complete nevigetion as Surviges of the contract of the contrac | 6.6 | -23.5 | -28.0 | -41.3 | -34.2 | 177.8 | 90.0 | 180.0 | 102.9 | -47.5 | 90.0 | -62.6 | Roll at 0.2 deg/sec |
| 00:51:67 | Start F.L.C. | 8 6 | -23.5 | -88 | -41.3 | -34.2 | 117.8 | 88.9 | -119.2 | 103.1 | 11.4 | 90.0 | -2.4 | 0.5 deg/sec thaneuver rate |
| 34:10:00 | Complete P.1.C; orient for navigation significant | 23.0 | | 8 87 | | 1 1 | -174.6 | 58.0 | -179.1 | 107.2 | -52.7 | 88.7 | -56.0 | Begin inertial bold |
| 34:20:00 | Perform SEH navigation signification of the DTC | 117. 5 | 2 | 8 | 0.6 | -13.3 | -174.6 | 57.9 | -179.0 | 107.2 | - 52.8 | 88.7 | -56.0 | 0.5 deg/sec maneuver rate |
| 34:50:00 | Complete navigation signtings; orient for F.1. | | | 2,46 | , 42 B | 34.8 | 177.8 | 0.06 | 180.0 | 102.7 | +64- | 90.0 | -63,3 | Roll at 0, 2 deg/sec |
| 35:05:00 | Start PTC | - 76. 3 | | | • | | : | | | | • | | | |

Table II. Spacecraft Attitude Data
(b) Translunar (Continued)

| a d | | | Attitude | | | | | to Earth | 44- | 77 | | | 1 | |
|-----------------|---|--------|----------|--------|-------------|--------|---------|------------------|--------------|--------|--------|--------|---------|--|
| | | Ditt | No. V | Boll | ¥.U | Angles | 1 | | LICE Deci | Thete | DL: | to Sun | ار ا | |
| | Event | (deg.) | (deg) | (deg.) | (deg) | (deg) | (deg) | (deg) | (deg) | (deg) | (deg.) | (deg.) | (deg) | Comments |
| 45:00:00 Com | Complete PTC; orient for navigation sightings | -92, 3 | -23.5 | -86.5 | -42.8 | -34.8 | 117.8 | 88.4 | -118.8 | 102.9 | 8.7 | 90.0 | -2.9 | 0.5 deg/sec maneuver rate |
| | Perform SLH navigation sightings | 6.9 | -19.1 | 130.1 | -135, 1 | -2.4 | -109.9 | 175.6 | 0.0 | 57.5 | 180.0 | 68,3 | 164.8 | Begin inertial hold |
| 46:00:00 Com | Complete navigation sightings | 6.9 | -19.1 | 130,1 | -135, 1 | -2.4 | -109.9 | 175.4 | 0.1 | 57.3 | 179.9 | 68,3 | 164.8 | Continue inertial hold |
| | Perform IMU alignment | 6.9 | -19.1 | 130.1 | -135,1 | -2.4 | -109.9 | 175.4 | 0.0 | 57.3 | 180,0 | 68,3 | 164.8 | Continue inertial hold |
| 46:30:00 Com | Complete IMU alignment | 6.9 | -19.1 | 130,1 | -135.1 | -2.4 | -109.9 | 175.3 | 0.0 | 57.2 | 180.0 | 68,3 | 164.8 | Continue inertial hold |
| 47:00:00 Initi | Initiate midcourse correction | 6.9 | -19.1 | 130,1 | -135.1 | -2.4 | -109.9 | 175.2 | 0.1 | 57.0 | 179.9 | 68.4 | 164.8 | Continue inertial hold |
| 47:10:00 Orie | Orient for navigation sightings | 6.9 | -19.1 | 130,1 | -135.1 | -2.4 | -109.9 | 175.2 | 0.1 | 57.0 | 179.9 | 68.4 | 164.8 | 0.5 deg/sec maneuver rate |
| | Perform SEH navigation sightings | 165.4 | -30,3 | -117.4 | 4.6 | 41.9 | 141.7 | 57.5 | 180.0 | 70.4 | -13, 3 | 58.3 | -0.1 | Begin inertial hold |
| | Complete navigation sightings; orient for PTC | 165,4 | -30,3 | -117.4 | 4. 6 | 41.9 | 141.7 | 57.5 | 179.9 | 70, 3 | -13.3 | 58, 3 | -0.1 | 0.5 deg/sec maneuver rate |
| 48:05:00 Star | Start PTC | -89.9 | -23.4 | -24.1 | -45.3 | -35.7 | 177.9 | 90.0 | 180.0 | 102.4 | -52.8 | 90.0 | -64,2 | Roll at 0, 2 deg/sec |
| | Complete PTC; orient for navigation sightings | -89.9 | -23.4 | 155.9 | -45,3 | -35.7 | -2.1 | 89.0 | 0.7 | 102.5 | 125.2 | 90.0 | 116.2 | 0. 5 deg/sec maneuver rate |
| | Perform SLH navigation aightings | 10.0 | -19.9 | 129.7 | -135,8 | 9.0 | -1111.3 | 178.7 | 0.3 | 57.5 | 180.0 | 65.8 | 165, 3 | Begin inertial hold |
| 57:50:00 Com | Complete navigation sightings; orient for PTC | 10.0 | -19.9 | 129.7 | -135.8 | 9.0 | -111.3 | 178.5 | 0.0 | 57.3 | 179.9 | 65.8 | 165, 3 | 0.5 deg/sec maneuver rate |
| | Ser PTC | -88.5 | -23.4 | -22.8 | -46.8 | -36.2 | 177.8 | 90.0 | 180.0 | 102.3 | -55.7 | 90.0 | -64.6 | Roll at 0, 2 deg/sec |
| | Complete PTC; orient for IMU alignment | -88.5 | -23.4 | -22.8 | -46.8 | -36.2 | 177.8 | 89.8 | -179.9 | 102.3 | -56.6 | 90.0 | -64, 5 | 0.5 deg/sec maneuver rate |
| | Perform IMU alignment | 10.9 | -20,8 | 25.1 | 107.2 | 6.8 | -98.0 | 179.7 | -153.1 | 57.6 | -75.4 | 2,5 | -90.0 | Pitch 90 deg, change to LOI-2 REFSMMAT, inertial hold |
| | Complete IMU alignment | 10.9 | -20.8 | 25.1 | 107.2 | 6.8 | -98.0 | 179.7 | -153, 3 | 57.7 | -75.4 | 64.5 | -90.0 | Continue inertial hold |
| _ | initiate midcourse correction | 10.9 | -20.8 | 25.1 | 107.2 | 6.8 | -98.0 | 179.7 | -153.8 | 58.0 | -75.4 | 64.4 | -90.0 | Continue inertial hold |
| | Orient for PTC | 10.9 | -20,8 | 25.1 | 107.2 | 6.8 | -98.0 | 179.6 | -154, 1 | 58.2 | -75.4 | 64.4 | -90.0 | Continue inertial hold |
| | gan PTC | 46.7 | 19.2 | -76.0 | 122.1 | -44.7 | 165.4 | 127.2 | 122.9 | 76.4 | 3.4 | 90.0 | 0.2 | Roll at 0.2 deg/sec |
| | Complete PTC | 46.7 | 19.2 | 164.0 | 122.1 | -44.7 | 45.6 | 127.7 | -117.0 | 80.5 | 127.9 | 90.0 | 120,0 | Terminate roll, inertial hold |
| | Perform DAU alignment | 46.7 | 19.2 | 164.0 | 122, 1 | -44.7 | 45.6 | 127.7 | -117.0 | 80.9 | 128.2 | 90.0 | 120.0 | Continue inertial hold |
| | Complete DAU alignment | 46.7 | 19.5 | 164.0 | 122. 1 | -44.7 | 45.6 | 127.7 | -117.0 | 81.7 | 129.1 | 90.0 | 120.0 | Continue inertial hold |
| | Start PTC | 46.7 | 19.2 | - 16.0 | 122.1 | -44.7 | 165.7 | 127.7 | 123.1 | 82.4 | 6.6 | 90.0 | 0.0 | Roll at 0.2 deg/sec |
| | Complete PTC; orient for DAU alignment | 46.7 | 19.2 | -76.0 | 122.1 | -44.7 | 165.7 | 127.9 | 123,3 | 92.4 | 19.9 | 90.0 | 0.0 | 0.5 deg/sec mansuver rate |
| 68:15:00 Perf | Perform IMU alignment | -52.3 | #.3 | 166.4 | -165.0 | 6.9 | 14.6 | 97.8 | -20.5 | 171.0 | -175.2 | 147.8 | 133.5 | Performed in LOI burn attitude, inertial hold |
| | Complete IMU alignment | -52, 3 | 44.3 | 166.4 | -165.0 | 6.9 | 14.6 | 7.26 | -20.5 | 173, 5 | -33,4 | 147.8 | 133, 5 | Continue inertial hold |
| 69:07:29 Initia | Initiate LOI-1 burn | -52,3 | 44, 3 | 166.4 | -165.0 | 6.9 | 14.6 | No line of sight | f sight | 97.9 | -15.2 | 147.8 | 133.5 | Continue inertial hold |

Table II. Spacecraft Attitude Data (c) Lunar Orbit

| (hr:min:sec) 69:11:35 69:11:35 69:20:00 69:20:00 69:20:00 70:14:12 Fine: 70:14:12 Fine: 70:55:13 Maney 71:55:13 Maney 71:50:26 Fine: 71:50:26 Fine: 72:22:47 Fine: 72:25:00 Maney 72:55:00 Maney 72:55:00 Maney 72:55:00 Maney 72:55:00 Maney 72:55:00 Maney | Event deg for communication MASFN line of sight mar umbra My realignment r to lunar observation and sight r to lunar observation and phy attitude might ASFN line of sight te local bold; begin inertial hold asr umbra IV realignment r to circularisation burn except rolled 180 deg except rolled 180 deg ere of sight deg to circularization burn deg to circularization burn | Aftitude (n mi) 59.4 59.4 775.1 775.1 167.3 167.3 103.0 103.0 103.0 105.2 168.2 168.2 168.2 168.2 168.2 168.5 | -10.1 -11.7 -11.7 -11.4 -1.4 -1.4 -1.4 -1.4 -1.4 | leg _ | Pitch (deg) -171.6 | Yaw Roll (deg) (deg) 6.9 0.5 | [일 원 | NGA OGA (deg) (deg) | (deg) | Theta Phi (deg) (deg) | Phi (deg) | Theta Phi (deg) (deg) | Theta Phi (deg) (deg | Phi (deg) | Comment |
|--|--|---|--|----------|--------------------------|------------------------------|------------|------------------------|--------|--------------------------|--------------|--------------------------|-------------------------|--------------|--------------------------|
| | 10 cutoff 10 deg for communication 12 mar umbra 13 IMU realignment 14 MSFN line of sight 15 MSFN line of sight 16 MSFN line of sight 17 mar to lunar observation and 18 graphy attitude 12 malight 13 mar to care to lune of sight 16 mar umbra 16 IMU realignment 17 mar umbra 18 MSFN line of sight 18 deg to circularization burn 18 de except rolled 180 deg 18 MSFN line of sight 180 deg to circularization burn 18 de except colled 180 deg | 59.4 75.1 167.3 167.3 103.0 103.0 103.0 103.0 103.0 103.0 104.5 | -10.1 -11.7 -11.4 9.6 9.6 | | .171.6 | | | | | | 44. | | | | |
| | 180 deg for communication Te MSFN line of sight IMU realignment MSFN line of sight MSFN line of sight graphy attitude Te walight The MSFN line of sight That local hold; begin inertial hold Thun rumbra IMU realignment de except rolled 180 deg MSFN line of sight MSFN line of sight MSFN line of sight | 75.1 167.3 167.3 103.0 103.0 103.0 103.0 103.0 103.0 104.5 | -11.7 -11.4 9.6 9.6 4.2 | | | | 0.5 -165.0 | 6.9 | 0.5 | No line of sight | a ignt | 147.8 147.7 | 4 | | Begin inertial hold |
| | re MSFN line of sight lunar umbra IMU realignment MSFN line of sight MSFN line of sight graphy attitude re to lunar observation and graphy attitude re MSFN line of sight inate local bold; begin inertial hold r lunar umbra n IMU realignment de except rolled 180 deg MSFN line of sight MSFN line of sight | 167. 3 167. 3 103. 0 103. 0 103. 0 103. 0 103. 0 103. 0 103. 0 104. 5 100. 1 | 9.6 | 123, 6 | -118.0 | | .5 -165.0 | 6.9 | -179.5 | No line of sight | f sight | 147.8 -32.3 | 3 | | Begin inertial hold |
| | lunar umbra IMU realignment MSFN line of sight graphy attitude search olunar observation and graphy attitude seanlight ire MSFN line of sight inate local bold; begin inertial bold r lunar umbra a IMU realignment de except rolled 180 deg MSFN line of sight 180 deg to circularization burn de | 167, 3 103, 0 103, 0 103, 0 103, 0 103, 0 103, 0 104, 5 100, 1 | 9,6 9,6 4,2 | 119.5 | -114.0 | 6.9 -179.5 | .5 -165.0 | 6.9 0 | -179.5 | 92.3 | 174.2 | 147.8 -32.3 | 3 | | Continue inertial hold |
| | MSFN line of sight Wer to lunar observation and graphy attitude r unlight ire MSFN line of sight inate local bold; begin inertial hold r lunar umbra a IMU realignment de except rolled 180 deg MSFN line of sight MSFN line of sight | 167.3 103.0 103.0 89.9 77.6 160.4 167.2 168.2 126.4 100.1 | 9.6 5.4 5.2 | 6.0 | 5, 3 | 6.9 -179.5 | .5 -165.0 | 6.9 0 | -179.5 | 93.0 | 174.2 | No line of sight | # | | Continue inertial hold |
| | wer to lunar observation and graphy attitude spaphy attitude studight ire MSFN line of sight insertial hold inset local hold; begin insertial hold r lunar umbra a IMU realignment wer to circularisation burn de accept rolled 180 deg MSFN line of sight MSFN line of sight ded deg to circularization burn ded deg to circularization burn ded were statement was made as a lung deg to circularization burn ded deg to circularization burn dege degree a sight degree and | 103.0 103.0 103.0 103.0 177.6 160.4 167.2 168.2 126.4 104.5 | 4.2 | 6.0 | 5.3 | 6.9 -179.5 | .5 -165.0 | | -179.5 | 93.0 | 174.2 | No line of sight | Ħ | | Continue inertial hold |
| | uver to lunar observation and apply attitude • unlight ire MSFN line of sight inate local bold; begin inertial bold • lunar umbra • IMU realignment de accept rolled 180 deg MSFN line of sight 180 deg to circularization burn de becopt rolled 180 deg | 103. 0 89. 9 77. 6 160. 4 167. 2 168. 2 126. 4 104. 5 | 4.2 | - 108.8 | 113, 3 | 6.9 -179.5 | .5 -165.0 | 6.9 0 | -179.5 | No line of sight | f sight | No line of sight | Ħ | | Continue inertial hold |
| | re unlight ire MSFN line of sight inate local bold; begin inertial bold i lunar umbra i IMU realigument de except rolled 180 deg MSFN line of sight de deg to circularization burn de de deg to circularization burn de de except rolled deg | 89.9 77.6 160.4 167.2 168.2 126.4 104.5 | | - 108.8 | -45.0 | 0.0 180.0 | 36. | 8 0.0 | 180.0 | No line of sight | f sight | No line of sight | ¥ | | Begin local hold |
| | tre MSFN line of sight inate local bold; begin inertial hold ! Junar umbra i IMU realigument de except rolled 180 deg MSFN line of sight 180 deg to circularization burn de | 77.6 160.4 167.2 168.2 126.4 104.5 | 1, 2 | -123.0 | -45.0 | 0.0 180.0 | .0 21.9 | 9 0.0 | 180.0 | No line of sight | f sight | 22.6 -154.7 | 7 | | Continue local hold |
| | inate local bold; begin inertial hold I lunar umbra I IMU realigument weer to circularisation burn MSFN line of sight MSFN line of sight de deg to circularization burn de | 160.4 167.2 168.2 126.4 104.5 | 11.2 | 118.4 | -45.0 | 0.0 180.0 | .0 -95.9 | 9 0.0 | 180.0 | 24.4 | 166.4 | 137.5 -164.8 | o o | | Continue local hold |
| | lunar umbra i IMU realignment de except rolled 180 deg MSFN line of sight 180 deg to circularization burn de | 167.2 168.2 126.4 104.5 100.1 | 6, 5 | 19.7 | -45.0 | 0.0 180.0 | .0 164.6 | 0.0 | .180.0 | 123.7 | 173.3 | 121.5 -11.9 | 6 | | Begin inertial hold |
| | uver to circularisation burn de except rolled 180 deg MSFN line of sight 180 deg to circularization burn de | 168.2 126.4 104.5 100.1 | 9.6 | 0.1 | -25.5 | 0.0 180.0 | .0 164.6 | 0.0 | 180.0 | 123.9 | 173.3 | No line of sight | Ħ | | Continue inertial hold |
| | uver to circularisation burn de except rolled 180 deg MSFN line of sight 180 deg to circularization burn de | 126.4 104.5 100.1 | 10.9 | -11.0 | -14.5 | 0.0 180.0 | .0 164.6 | 0.0 9 | 180.0 | 124.0 | 173.3 | No line of sight | Ħ | | Continue inertial hold |
| | MSFN line of sight 180 deg to circularization burn de | 100.1 | 8.7 | -85.1 | 73.6 | 0.0 180.0 | .0 180.0 | 0.0 | 180.0 | 109. 1 | 174. 2 | No line of sight | Ħ | | Begin inertial hold |
| | 180 deg to circularization burn de | 100.1 | 4.5 | - 108. 2 | 8.96 | 0.0 180.0 | .0 180.0 | 0.0 | 180.0 | No line of sight | f sight | No line of sight | # | | Continue inertial hold |
| | , | 9 | 3,5 | -112.9 | 101.6 | 0.0 | 0.0 180.0 | 0.0 | 0.0 | No line of sight | f sight | No line of sight | ¥ | | Begin inertial hold |
| 23.00.01 Fater | Cutor annihitht | ア・ナス | - | -124.3 | 113.1 | 0.0 | 0.0 180.0 | 0.0 | 0.0 | No line of | of sight | 136.5 165.2 | 2 | | Continue inertial hold |
| | de mineral de la faction de la company de la | . 6 | 8 01 - | 9 691 | 1.79.7 | | | o | 0.0 | No line of sight | f sight | 136.4 165.2 | 2 | | Continue inertial hold |
| | Circularization burn initiation | 23.0 | | 0.701 | | | | ٥ | | No line of sight | . sirbt | | ~ | | Continue inertial hold |
| - | Circularization burn cuton | 0.46 | | 1.63. | | | | | Ť | 11.0% | 1 | , | | | Regin local hold |
| 73:40:00 Maney | Maneuver to landmark training photography attitude | 59.0 | - 12. 3 | 141.3 | -52.5 | 0.0 | | | | o agu ou | | | • | | |
| 73:47:48 Acqui | Acquire MSFN line of sight | 58.8 | -11,3 | 117.1 | - 52, 5 | 0.0 180.0 | .0 -103.6 | | | 33.0 | 169.9 | • | | | Continue local hold |
| 74:14:16 Start : landin photog | Start mamual pitch rate for peeudo landing eite landmark training photography | 58.0 | 2.8 | 37. 3 | -52.5 | 0.0 180.0 | .0 176.1 | 1 0.0 | 180.0 | 113. 2 | 174.0 | 132. 7 - 13. 9 | 6 % | ٠ • | Begin manual pitch rate |
| 74:16:33 Termi | Terminate manual pitch; pitch - 70 deg | 58.0 | 4.2 | 30.5 | -72.4 | 0.0 180.0 | .0 149.3 | 3 0.0 | | 139.9 | 171.5 | 106.4 -10.6 | 6 69.3 | 9.9 | Begin inertial hold |
| | Enter lunar umbra | 57.9 | 7.4 | 11.4 | -53.2 | 0.0 180.0 | .0 149.3 | 3 0.0 | 180.0 | 140.1 | 171.4 | No line of sight | Ħ | | Continue inertial hold |
| | Begin IMU realignment | 57.8 | 10.8 | - 10.9 | -31.1 | 0.0 180.0 | 1.0 149.3 | 3 0.0 | 180.0 | 140.2 | 171.4 | No line of sight | Ħ | | Continue inertial hold |
| 74:55:00 Maneugraph | Maneuver to orbital navigation photo- graphy attitude | 58.3 | 8.4 | -87,7 | -90.0 | 0.0 180.0 | 1.0 14.9 | 9 0.0 | 180.0 | 84. 6 | 5, 5 | No line of sight | Ħ | | Begin local hold |
| 74:59:49 Lose | Lose MSFN line of sight | 58.5 | 5,8 | -102.3 | -90.0 | | 0.3 | 3 0.0 | | No line of sight | f sight | 9 | ¥ | | Continue local hold |
| 75:09:00 Enter | Enter sunlight | 58.8 | 0.2 | -129.7 | -90.0 | 0.0 180.0 | | | 180.0 | No line of sight | f sight | - | 7 | | Continue local hold |
| | Roll 180 deg; continue orbital navigation photography | 58.9 | -11.9 | 123. 5 | -90.0 | 0.0 | 0.0 -133.7 | 7 0.0 | 0.0 | No line of sight | f sight | 169.2 70.5 | s. | | Begin local hold |
| 75:46:11 Acqui | Acquire MSFN line of sight | 58.8 | -11.4 | 116.4 | -90.0 | 0.0 | 0.0 -140.3 | 3 0.0 | 0.0 | 70.6 | .5.8 | - | 7 | | Continue local hold |
| | Maneuver to landmark evaluation attitude | 58.3 | -5.4 | 74.7 | 5.0 | | | ö | | 18.4 | -17.5 | | | | Begin local hold |
| 76:10:20 Start of pac | Start pitch rate for landmark evaluation of pseudo landing site | 58.1 | : | 43.8 | 5.0 | 0.0 | 0.0 -118.6 | | | 49.4 | -7.2 | | 30. 7 | -174.7 | -0, 3 deg/sec pitch rate |
| 76:14:49 Term | Terminate pitch rate; roll 180 deg | 57.9 | + .0 | 30, 5 | -62,1 | 0.0 180.0 | | | | 129. 7 | 172.9 | 117.5 -11.5 | 5 79,3 | 4.4 | Begin inertial hold |
| | Enter lunar umbra | 57.9 | 7.7 | 10.4 | -41.9 | 0.0 180.0 | 1.0 160.7 | | | 129.9 | 172.9 | No line of sight | 2 | | Continue inertial hold |
| | Begin IMU realignment | 57.8 | 11.2 | -15.7 | -16.0 | 0.0 180.0 | 1.0 160.7 | 7 0.0 | 180.0 | 130.1 | 172.9 | No line of sight | * | | Continue inertial hold |

Table II. Spacecraft Attitude Data (c) Lunar Orbit (Continued)

| Mission | | Selen | Selenographic Position | osition | Loca | Local Horizontal | ita | Gimba | IMU Gimbal Angles | | Look Angles To Earth | | S. S. | | Look Angles Fo Landmari | lee Ark | |
|----------------------|---|--------------------|------------------------|--------------------|----------------|------------------|---------------|-------------|----------------------|-----------|-------------------------|----------|------------------|----------|----------------------------|------------|--------------------------|
| Time (hr:min:sec) | Event | Altitude (n mi) | Latitude (deg) | Longitude (deg) | Pitch (deg) | Yaw (deg) | Roll (deg) | IGA Geg) | MGA (deg) | | Theta P | | Theta P | Phi | Theta Phi | Phi | Comment |
| | | | | 8 - | | | | | | | | | 4 | | | | |
| 01:96:07 | Lose Mar n line of signt | 58.5 | 0.0 | -102.5 | 69.0 | | | 160.7 | | | No line of sight | | No line of sight | 볊 | | • | Continue inertial hold |
| 77:00:00 | Maneuver to landmark sighting attitude | 58.5 | 4.9 | -108.0 | 5.0 | 0.0 | 0.0 | 90.6 | 0.0 | 0.0 | No line of sight | | No line of sight | ight | | М | Begin local hold |
| 77:07:35 | Enter sunlight | 58.8 | 0.2 | -130.7 | 5.0 | 0.0 | 0.0 | 67.6 | 0.0 | 0.0 | No line of sight | ight | 5.7 | 4.2 | | Ü | Continue local hold |
| 77:30:19 | Start pitch rate for 2nd control point landmark sighting | 59.1 | -11.4 | 160.7 | 5.0 | 0.0 | 0.0 | -1.4 | 0.0 | 0.0 | No line of sight | | 45.0 1 | | 30.7 -1 | -174.5 - | -0.3 deg/sec pitch rate |
| 77:34:48 | Terminate pitch rate; maneuver to landmark sighting attitude | 59.0 | -12.2 | 146.8 | 5.0 | 0.0 | 0.0 | -15.0 | 0.0 | 0.0 | No line of sight | | 58.3 1 | 12.0 14 | 145, 3 -1 | -175.2 B | Begin local hold |
| 77:44:32 | Acquire MSFN line of sight | 58.8 | -11.5 | 116.0 | 5.0 | 0.0 | 0.0 | 4 | 0.0 | 0.0 | 24.7 -167.0 | , | 87.4 | 10. 2 | | O | Continue local hold |
| 78:08:36 | Start pitch rate for pseudo landing site landmark sighting | 58.1 | 0.9 | 43.8 | 5.0 | 0.0 | 0.0 | | 0.0 | 0.0 | 49.4 | -7.1 15 | 157.9 2 | 28.0 | 30.6 -1' | -177.1 | -0, 3 deg/sec pitch rate |
| 78:13:05 | Terminate pitch rate; roll 180 deg | 58.0 | 3.8 | 30.5 | -62.1 | 0.0 | 180.0 | 161.8 | 0.0 | 180.0 | 129.8 17 | 173.0 11 | 118.5 -1 | -11.6 | 79.0 | 2.4 B | Begin inertial hold |
| 78:20:05 | Enter lunar umbra | 57.9 | 1.1 | 9.4 | -34.7 | 0.0 | 180.0 | 161.8 | 0.0 | 180.0 | | 173.0 N | 0 | | | | Continue inertial hold |
| 78:35:00 | Begin IMU realignment | 57.9 | 12.3 | -36.5 | 4.5 | 0.0 | 180.0 | 161.8 | 0.0 | 180.0 | 130, 3 17. | 173.0 No | No line of eight | 其 | | υ | Continue inertial hold |
| 78:56:32 | Lose MSFN line of sight | 58.5 | ₽.9 | -103.0 | 68.5 | 0.0 | 180.0 | 161.8 | 0.0 | 180.0 N | No line of sight | _ | No line of sight | Ħ | | Ų | Continue inertial hold |
| 79:06:00 | Maneuver to landmark sighting attitude | 58.7 | 0.3 | -131.1 | 5.0 | 0.0 | 0.0 | 68.2 | 0.0 | 0.0 | No line of sight | _ | No line of sight | Ą | | a) | Begin local hold |
| 79:06:12 | Enter sumlight | 58.7 | 0.2 | -131.7 | 5.0 | 0.0 | 0.0 | 67.6 | 0.0 | 0.0 | No line of sight | | 26.6 15 | 156.9 | | Ú | Continue local hold |
| 79:28:36 | Start pitch rate for 2nd control point landmark sighting | 59.0 | -11.3 | 1 60. 7 | 5.0 | 0.0 | 0.0 | -0.3 | 0.0 | 2 0.0 | No line of sight | | 4.1 | 14.7 | 30. 7 -173. | | -0. 3 deg/sec pitch rate |
| 79:33:05 | Terminate pitch rate; maneuver to land- mark sighting attitude | 59.0 | -12.2 | 146.8 | 9.0 | 0.0 | 0.0 | -13.9 | 0.0 | ž 0.0 | No line of sight | | 57.3 1 | 12. 1 14 | 145.4 -17 | -174.7 B | Begin local hold |
| 79:42:30 | Acquire MSFN line of sight | 58.8 | -11.6 | 117.6 | 5.0 | 0.0 | 0.0 | -42.5 | 0.0 | 0.0 | 25.6 -167.5 | | 85.4 10 | 10.2 | | ŭ | Continue local hold |
| 80:06:52 | Start pitch rate for pseudo landing site landmark sighting | 58.1 | 0.7 | 43.8 | 5.0 | 0.0 | 0.0 | -116.4 (| 0.0 | 0.0 | 49.4 | -7.0 15 | 157.0 20 | 26.8 3 | 30.5 -179. | • | -0.3 deg/sec pitch rate |
| 80:11:21 | Terminate pitch rate; roll 180 deg | 58.0 | 3,6 | 30.5 | -62.1 | 0.0 | 180.0 | 162.9 | 0.0 | 180.0 12 | 129.8 173.1 | | 119.5 -11.7 | | 78.8 | 0.4 B | Begin inertial bold |
| 80:18:41 | Enter lunar umbra | 57.9 | 7.8 | 8.4 | -39.8 | | | 162.9 | 0.0 | | 130.0 173.0 | _ | 5 | | | | Continue (name(a) hold |
| 80:32:00 | Begin IMU realignment | 57.8 | 12.0 | -32, 7 | 9.0 | | | | | | | ~ | | ä | | ŭ | Continue inertial hold |
| 80:54 :50 | Lose MSFN line of sight | 58.5 | 6.5 | -101.9 | 68.9 | 0.0 | 180.0 | 162.9 | 0.0 | 180, 0 No | No line of sight | _ | No line of sight | Ą | | ŭ | Continue inertial hold |
| 81:00:00 | Maneuver to landmark sighting attitude | 58.6 | 3,2 | -118.4 | 5.0 | 0.0 | 0.0 | 82.2 | 0.0 | 0.0 | No line of sight | | No line of sight | Ħ | | Ā | Begin local hold |
| 81:04:48 | Enter sunlight | 58. 7 | 0.2 | -132.7 | 5.0 | 0.0 | 0.0 | 67.7 0 | 0.0 | 0.0 | No line of sight | | 26.3 156.6 | ٠ | | ŭ | Continue local hold |
| 11:12:25 | Start pitch rate for 1st control point landmark sighting | 58.9 | -4.7 | -155,4 | 5.0 | 0.0 | 0.0 | 9.4 | 0.0 | ŏ.0.0 | No line of sight | | 10.3 99 | 99.2 | 33, 7 156. | œ | -0.3 deg/sec pitch rate |
| 81:16:54 | Terminate pitch rate; maneuver to landmark sighting attitude | 59.0 | -7.2 | -168.9 | 5.0 | 0.0 | 0.0 | 31.0 0 | 0.0 | 0.0 | No line of sight | | 15.6 40 | 40.9 14 | 147.8 160. | • | Begin local hold |
| 81:26:53 | Start pitch rate for 2nd control point landmark eighting | 59.1 | -11.3 | 160.7 | 5. 0 | 0.0 | 0.0 | 0.7 0 | 0.0 | 0.0 | No line of sight | | 43.1 14 | 14.9 30 | 30.8 -17 | -173.3 -0 | -0, 3 deg/sec pitch rate |
| 81:31:22 | Terminate pitch rate; maneuver to landmark sighting attitude | 59.0 | -12.1 | 146.8 | 5.0 | 0.0 | 0.0 | -12.8 0 | 0.0 | 0.0 No | No line of sight | | 56.4 12 | 12, 2 14 | 144.9 -169.9 | | Begin local hold |
| 81:40:51 | Acquire MSFN line of sight | 58.8 | -11.6 | 117.2 | 5.0 | 0.0 | 0.0 | -41.7 0 | 0.0 | 0.0 | 25.4 -167.5 | | 84.6 10 | 10.2 | | ပိ | Continue local hold |
| 61:44:48 | Start pitch rate for 3rd control point landmark sighting | 58.7 | - 10.6 | 105.1 | 5.0 | 0.0 | 0.0 | -53.6 0. | | 0.0 | 13.8 -157.5 | .96 5 | .4 10.2 | | 30.8 169. | 10 | -0. 3 deg/sec pitch rate |
| 81:49:17 | Terminate pitch rate; maneuver to landmark sighting attitude | 58.6 | 8; 8; | 91.4 | 9.0 | 0.0 | 0.0 | -67.2 0. | | 0.0 | 5.3 -81.3 | 3 109. | . 8 10.8 | | 145.2 170 | 170. 6 P | Degin local hold |
| 82:05:08 | Start pitch rate for pseudo landing site landmark sighting | 58.0 | 0.5 | 43.8 | 5.0 | 0.0 | 0.0 | -115.3 0 | 0.0 | 0.0 | 49.4 -7.0 | 0 156.1 | . 1 25.8 | | 30.4 17 | 178.3 -Q | -0.3 deg/sec pitch rate |
| | | | | | | | | | | | | | | | | | |

Table II. Spacecraft Attitude Data (c) Lunar Orbit (Continued)

| Present Claim Cl | Mission | | Selen | oeraphic P | omition | Local | Local Horizontal | ntal | Gim | IMU bal Angle | | Look Angles To Earth | | ₹3 | | Look Angles To Landmark | 9 4 1 | |
|--|----------------------|---|--------------------|-------------------|--------------------|----------------|------------------|---------------|--------------|------------------|-------|-------------------------|--------|------------------|----------|----------------------------|----------|--------------------------|
| Enter nause pitch rate; roll 180 deg | Time (hr:min:eec) | Event | Altitude (n mi) | Latitude (deg) | Longitude (deg) | Pitch (deg) | Yaw (deg) | Roll (deg) | IGA (deg) | MGA (deg) | de g | | · | Theta I (deg) (c | (deg) | Theta (deg) | (deg) | Comment |
| Enter number and the sequence of the sequence | 67.09.33 | Terminate nitch rate: voll #80 dee | 58.0 | 4.6 | 30. 5 | -62.1 | | 80.0 | 164.0 | | 180.0 | | | . 5.021 | -11.8 | 78.6 | -1.6 | Begin inertial hold |
| Lear Manner to light and the set of s | 62.67.50 | Enter lines company | 67.9 | | 7. | 38.8 | | 0.08 | 164.0 | 0.0 | 180.0 | ٠ | 73, 1 | No line of | of sight | | | Continue inertial hold |
| Parameter to landmark sighting stitude 58.4 2.3 123.6 5.0 0.0 0.0 78.1 0.0 0 | 93:30:00 | Baris 1941 assistantes | | 12.0 | 3 2 | -0.3 | | 0.08 | 164.0 | | 0.081 | | 73.1 | No line of sight | eight | | | Continue inertial hold |
| Exter unlight between to landar at sighting attitude 58.7 1 2.13.1 5.0 0.0 0.0 0.0 78.1 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0 | 00:00:70 | Degiti two restigitions | | | | , , | | | 0 77 | | 0 081 | No line of | ie ht | No line of sight | sight | | | Continue inertial hold |
| Managery to bindran's sighting attitude Shart pitch rate for ist control point Shart pitch rate for ist control point Terminate pitch rate for precede landing site Begin IMV realignment Managery to define and solar corona Shart pitch rate for precede landing site Managery to define of sight Managery to be and solar corona Shart hand runhan Managery to define of sight Managery to be and solar corona Shart hand runhan Sha | 82:52:49 | Lose MSFN line of sight | 58.4 | | -102.1 | 1 | | | 2.6 | | | M- H- | 1 | Me line of sight | 1 | | | Regin local hold |
| Exart pich rate for lat control point Sart pich rate for lat control point Landmark sighting Acquire MSTN line of sight Landmark sighting attitude Sart pich rate for lat control point Landmark sighting attitude Acquire MSTN line of sight Acquire MSTN line of sight Masserver to other land arising Exart running and sight Acquire MSTN line of sight Masserver to other land arising Exart running and sight Masserver to other land arising Exart running attitude Sart sighting attitude Acquire MSTN line of sight Masserver to other land arising Masserver to land arising Masserv | 83:00:00 | Maneuver to landmark sighting attitude | 58.7 | 2.3 | - 123. 6 | 0.5 | 0.0 | 0.0 | 18.1 | 0.0 | o . | No line of | n Bu | No line of | | | | Degin communication |
| Deciminate pitch rate control point 99, 0 -4, 5 -155, 4 5, 0 0, 0 0, 0 45, 7 0, 0 0, 0 0, 0 10 10 10 10 10 | 83:03:24 | Enter sunlight | 58.8 | 0.2 | -133.7 | 5.0 | 0.0 | 0.0 | 67.7 | 0.0 | 0.0 | No line of | ight | | 156. / | | | Continue tocal noid |
| Perminate pitch rate; manaver to bundance spitch arte; manaver to bundance sighting attitude 59.1 11.12 160.7 5.0 0.0 0.0 1.18 0.0 0.0 0.0 landmark sighting attitude 59.1 11.12 160.7 5.0 0.0 0.0 11.8 0.0 0.0 0.0 landmark sighting attitude 59.1 11.1 11.6 5.0 0.0 0.0 0.0 11.8 0.0 0.0 0.0 landmark sighting attitude 58.9 11.1 11.2 160.7 5.0 0.0 0.0 0.0 11.8 0.0 0.0 0.0 landmark sighting attitude 58.9 11.1 11.2 160.7 5.0 0.0 0.0 0.0 1.2 5.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 | 83:10:42 | Start pitch rate for 1st control point landmark sighting | 59.0 | -4.5 | -155.4 | 5.0 | 0.0 | 0.0 | 45.7 | 0.0 | 0.0 | No line of | right | 10.5 | 104. 6 | 33, 3 | 158.6 | -0.3 deg/sec pitch rate |
| Indianate for 2nd control point 59.1 -11.2 160.7 5.0 0.0 0.0 1.18 0.0 0.0 Indianate stipfting attitude 58.0 -12.1 146.8 5.0 0.0 0.0 11.18 0.0 0.0 Indianate stipfting attitude 58.0 -11.7 116.9 5.0 0.0 0.0 -40.8 0.0 0.0 Start pitch rate for 3rd control point 58.7 -10.7 105.1 5.0 0.0 0.0 -52.5 0.0 0.0 Indianate stipfting attitude 58.0 -10.7 105.1 5.0 0.0 0.0 -52.5 0.0 0.0 Indianate stipfting attitude 58.0 3.2 30.5 -62.1 0.0 66.1 0.0 0.0 Indianate stipfting attitude 58.0 3.2 30.5 -62.1 0.0 66.1 0.0 0.0 Indianate stipfting attitude 58.0 3.2 30.5 -62.1 0.0 66.5 0.0 0.0 Indianate stipfting attitude 58.0 3.2 30.5 -62.1 0.0 66.5 0.0 0.0 Indianate stipfting attitude 58.0 3.2 30.5 -62.1 0.0 66.5 0.0 0.0 Indianate stipfting attitude 58.0 3.2 30.5 -62.1 0.0 66.5 0.0 0.0 Indianate stipfting attitude 58.0 3.2 30.5 -62.1 0.0 66.5 0.0 0.0 Indianate stipfting attitude 58.0 3.2 30.5 -62.1 0.0 66.5 0.0 0.0 Indianate stipfting attitude 58.0 3.2 30.5 -62.1 0.0 66.5 0.0 66.0 60.0 Indianate stipfting attitude 58.0 3.2 30.5 -62.1 0.0 66.5 0.0 60.0 60.0 Indianate stipfting attitude 58.0 3.2 3.2 3.2 3.2 3.0 60.0 60.0 60.0 60.0 Indianate stipfting attitude 58.0 0.0 0.0 60.0 60.0 60.0 60.0 60.0 Indianate stipfting attitude 58.0 0.1 60.0 60.0 60.0 60.0 60.0 60.0 60.0 60.0 Indianate stipfting attitude 58.0 0.1 60.0 | 83:15:11 | Terminate pitch rate; maneuver to landmark sighting attitude | 59.0 | -7.0 | -168.9 | | 0.0 | 0.0 | 32. 1 | 0.0 | 0.0 | No line of | ight | 14.9 | 43.3 | 147.6 | 162.4 | Begin local hold |
| Perminate pitch rate; maneuver to chain at the maneuver to search maneuver search search maneuver search search maneuver s | 83:25:09 | Start pitch rate for 2nd control point landmark sighting | 59.1 | -11.2 | 160.7 | 5.0 | 0.0 | 0.0 | 1.8 | 0.0 | 0.0 | No line of | eight | 42.2 | 15.2 | 30.8 - | - 172. 7 | -0.3 deg/sec pitch rate |
| Acquire MSFN line of sight Ser. 7 -10.7 116.9 5.0 0.0 0.0 -40.8 0.0 0.0 0.0 Start pitch rate for 3rd control point Ser. 7 -10.7 116.1 15.0 0.0 0.0 -22.5 0.0 0.0 Indicator stighting Terminate pitch rate; managerer to Ser. 10.7 116.1 15.0 0.0 0.0 -66.1 0.0 0.0 Start pitch rate for peeudo landing site Ser. 10.3 43.8 5.0 0.0 0.0 -66.1 0.0 0.0 Start pitch rate for peeudo landing site Ser. 10.3 43.8 5.0 0.0 0.0 -114.2 0.0 0.0 Ser. 10.3 43.8 5.0 0.0 0.0 146.1 0.0 0.0 Emer hunar umbra Ser. 10.3 18.0 18.0 18.0 18.0 18.0 18.0 18.0 18.0 | 83:29:38 | Terminate pitch rate; maneuver to landmark sighting attitude | 59.0 | -12.1 | 146.8 | 5.0 | 0.0 | 0.0 | -11.8 | 0.0 | 0.0 | No line of | • ight | 55.4 | 12.3 | 144.8 | -169.0 | Begin local hold |
| Description Sert pitch rate for 3rd constrol point Se. 7 | 83:39:13 | Acquire MSFN line of sight | 58.9 | -11.7 | 116.9 | 5.0 | 0.0 | 0.0 | -40.8 | 0.0 | 0.0 | | 67.5 | 84.0 | 10.2 | | | Continue local hold |
| Terminate pitch rate; maneuver to 58.6 -8.9 91.4 5.0 0.0 0.0 -66.1 0.0 0.0 landmarks ighting attitude landmarks ighting attitude landmarks ighting record landing site 58.1 0.3 43.8 5.0 0.0 0.0 -114.2 0.0 0.0 landmarks ighting attitude sale begin into darks ighting attitude sale sold arks idea and solar corona 58.2 9.7 7.8 6.4 -37.8 0.0 180.0 165.1 0.0 180.0 photography attitude landmarks corona 58.2 9.7 -83.6 -20.0 0.0 180.0 165.1 0.0 180.0 photography attitude sale solar corona 58.7 1.4 -128.7 -70.0 0.0 180.0 75.5 0.0 180.0 photography attitude sale solar corona 58.8 0.1 1.4 128.7 -70.0 0.0 180.0 75.5 0.0 180.0 photography attitude sale solar so | 83:43:05 | Start pitch rate for 3rd control point landmark sighting | 58. 7 | - 10. 7 | 105.1 | 5.0 | 0.0 | 0.0 | -52.5 | 0.0 | 0.0 | • | 57.7 | 95.4 | | | | -0.3 deg/sec pitch rate |
| Start pitch rate for peeudo landing site | 83:47:34 | Terminate pitch rate; maneuver to landmark sighting attitude | 58.6 | -8.9 | 91.4 | 5.0 | 0.0 | 0.0 | - 66.1 | 0.0 | 0.0 | ۳ | 80.9 | 108.8 | | | 169.3 | Begin local hold |
| Terminate pitch rate; roll 180 deg 58.0 3.2 30.5 -62.1 0.0 180.0 165.1 0.0 180.0 Exter hunar umbra Begin LMU realignment 57.8 11.3 -21.6 -10.1 0.0 180.0 165.1 0.0 180.0 Manaverer to darkaide and solar corona 58.2 9.7 -83.6 -20.0 0.0 180.0 165.1 0.0 180.0 180.0 photography attitude Lose MSFN line of sight or photography attitude S8.4 6.8 -102.5 -20.0 0.0 180.0 75.5 0.0 180.0 photography attitude S8.8 0.1 1.34.7 -70.0 0.0 180.0 -1.1 0.0 180.0 180.0 or bital navigation photography attitude S8.8 -11.9 118.6 -110.0 0.0 180.0 -1.2 0.0 180.0 or bital navigation photography S8.8 0.1 118.4 -128.7 -70.0 0.0 180.0 -1.2 0.0 180.0 or bital navigation photography S8.8 0.1 118.4 -110.0 0.0 180.0 0.0 -153.3 0.0 0.0 0.0 180.0 Begin LMU realignment 57.9 7.8 5.4 -110.0 0.0 180.0 180.0 180.0 Begin LMU realignment 57.9 12.3 -42.4 -40.0 0.0 180.0 180.0 180.0 180.0 Exter sunlight S8.8 -11.9 1135.7 -45.0 0.0 180.0 180.0 180.0 Exter sunlight S8.8 -11.9 1135.7 -45.0 0.0 180.0 1 | 84:03:24 | Start pitch rate for pseudo landing site landmark sighting | 58.1 | 0.3 | 43.8 | 5.0 | 0.0 | | 114.2 | 0.0 | 0.0 | 4 9. 4 | -6.9 | 155. 2 | 8.4.8 | 30. 4 | 175.9 | -0. 3 deg/sec pitch rate |
| Exter lunar umbra Begia IMC realignment Body Sequence of arkaide and solar corona Begia IMC realignment Maneuver to darkaide and solar corona Begia IMC realignment Lose Markailla of arkaide and solar corona Body Saphy attitude Lose Markailla of sight Maneuver to orbital navigation Pitch 40 deg; roll 180 deg; continue Sab | 84:07:53 | Terminate pitch rate; roll 180 deg | 58.0 | 3.2 | 30, 5 | -62.1 | | | 165.1 | | 180.0 | | 73.2 | . 5.121 | -11.9 | 78.3 | -3.7 | Begin inertial hold |
| Begin LMU restligament 57.8 11.3 -21.6 10.1 0.0 180.0 | 84:15:54 | Enter lunar umbra | 57.9 | 7.8 | 6.4 | -37.8 | | 180.0 | 165.1 | | 0.081 | | 73.2 | No line of sight | • ight | | | Continue inertial hold |
| Maneuver to darkside and solar corona 58.2 9.7 -83.6 -20.0 0.0 180.0 94.4 0.0 180.0 Dose MSFN line of sight 58.4 6.8 -102.5 -20.0 0.0 180.0 75.5 0.0 180.0 Maneuver to orbital navigation 58.7 1.4 -128.7 -70.0 0.0 180.0 -7.1 0.0 180.0 Enter a unlight Enter a unlight 58.8 0.1 -114.7 -70.0 0.0 180.0 -7.2 0.0 180.0 Acquire MSFN line of sight 58.8 -11.9 118.5 -110.0 0.0 -153.3 0.0 0.0 Begin IMU realignment 57.9 7.8 5.4 -110.0 0.0 0.0 92.9 0.0 0.0 Lone MSFN line of sight 57.9 7.8 5.4 -10.0 0.0 145.9 0.0 0.0 Begin IMU realignment 57.9 7.8 5.4 -10.0 0.0 145.9 0.0 180.0 | 84:25:00 | Begin IMU realignment | 57.8 | 11.3 | -21.6 | - 10. 1 | 0.0 | 0.081 | 165.1 | | 0.081 | | 73.2 | No line of sight | sight | | | Continue inertial hold |
| Lose MSFN line of sight 58.4 6.8 -102.5 -20.0 0.0 180.0 75.5 0.0 180.0 Maneuver to orbital navigation photography attitude 58.7 1.4 -128.7 -70.0 0.0 180.0 -1.1 0.0 180.0 Pitch 40 deg; roll 180 deg; continue 58.8 0.1 -134.7 -70.0 0.0 180.0 -7.2 0.0 180.0 Pitch 40 deg; roll 180 deg; continue 58.8 -11.9 118.6 -110.0 0.0 -153.3 0.0 0.0 Acquire MSFN line of sight 58.8 -11.9 118.3 -110.0 0.0 -153.3 0.0 0.0 Begin IMU ralignment 57.9 7.8 5.4 -110.0 0.0 180.0 180.0 180.0 Lose MSFN line of sight 57.9 12.3 -12.4 -10.0 0.0 185.9 0.0 180.0 Enter aunlight 58.4 6.8 -104.0 -45.0 0.0 185.9 0.0 180.0 Acquir | 84:45:00 | Maneuver to darkside and solar corona photography attitude | 58.2 | 9.1 | -83.6 | -20,0 | 0.0 | 180.0 | 4.4 | | 180.0 | 158.0 | 14.0 | No line of sight | ight. | | | Begin local hold |
| Maneuver to orbital mavigation 58.7 1.4 -128.7 -70.0 0.0 180.0 -1.1 0.0 180.0 No line of photography attitude Enter sumlight Disch doeg; puth of deg; routinue 58.8 -11.9 118.6 -110.0 0.0 -57.2 0.0 180.0 No line of photography Acquire MSFN line of sight 58.8 -11.9 118.3 -110.0 0.0 -153.3 0.0 0.0 90.3 Begin IMU realignment 57.9 7.8 5.4 -110.0 0.0 180.0 145.9 0.0 150.1 Lose MSFN line of sight 58.4 6.8 -102.7 49.5 0.0 180.0 145.9 0.0 180.0 150.1 Acquire MSFN line of sight 58.4 6.8 -102.7 49.5 0.0 180.0 180.0 180.0 180.0 180.0 180.0 180.0 180.0 180.0 180.0 180.0 180.0 180.0 180.0 180.0 180.0 180.0 180.0 180.0 | 84:51:14 | Lose MSFN line of sight | 58.4 | 6.8 | - 102. 5 | -20.0 | | 0.081 | 75.5 | | 0.081 | No line of | | No line of sight | • ight | | | Continue local hold |
| Enter sunlight 58.8 0.1 -134.7 -70.0 0.0 180.0 -7.2 0.0 180.0 No line of orbital and pategraphy Acquire MSFN line of sight 58.8 -11.9 118.6 -110.0 0.0 0.0 -153.3 0.0 0.0 No line of orbital and pategraphy Acquire MSFN line of sight 58.8 -11.9 118.3 -110.0 0.0 0.0 -153.6 0.0 0.0 92.9 0.0 0.0 90.3 Roll 180 deg; pitch 57.5 deg 57.9 7.8 8.5 0.8 -52.5 0.0 145.9 0.0 156.0 - Begin Indu resligament 57.9 12.3 -42.4 -10.0 0.0 145.9 0.0 156.0 - Lose MSFN line of sight 58.4 6.6 -104.0 -45.0 0.0 145.9 0.0 180.0 150.4 Enter sunlight 58.7 0.1 -104.0 0.0 146.0 0.0 180.0 180.0 180.0 180.0 180.0 | 09:00:00 | Maneuver to orbital navigation photography attitude | 58.7 | † : | -128.7 | -70.0 | | 180.0 | 7. | | 180.0 | No line of | ight | 4 | sight | | | Begin local hold |
| Pitch 40 deg; roll 180 deg; continue 58.8 -11.9 118.6 -110.0 0.0 0.0 -153.3 0.0 0.0 No line of orbital navigation photography Acquire MSFN line of sight Begin DdU resligament Lose MSFN line of sight Maneuver to lunar observation attitude 58.4 6.6 -104.0 -45.0 0.0 180.0 145.9 0.0 180.0 150.1 Enter sunlight Acquire MSFN line of sight Acquire MSFN line of sig | 85:02:00 | Enter sunlight | 58.8 | 0.1 | -134, 7 | - 70.0 | | | -7.2 | | 180.0 | No line of | | | -166.9 | | | Continue local hold |
| Acquire MSFN line of sight 58.8 -11.9 118.3 -110.0 0.0 0.0 -153.6 0.0 0.0 90.3 Enter lumar umbra 57.9 7.8 5.4 -110.0 0.0 0.0 92.9 0.0 0.0 156.0 -156.0 Enter lumar umbra 57.9 12.3 -42.4 -110.0 0.0 180.0 145.9 0.0 180.0 156.1 Lose MSFN line of sight 57.9 12.3 -42.4 -10.0 0.0 180.0 145.9 0.0 180.0 150.4 Maneuver to lunar observation attitude 58.4 6.6 -104.0 -45.0 0.0 180.0 50.1 10.0 180.0 No line of Enter sunight 58.8 -11.8 117.9 -45.0 0.0 180.0 -87.8 0.0 180.0 No line of 180.0 No | 85:37:00 | Pitch 40 deg; roll 180 deg; continue orbital navigation photography | 58.8 | -11.9 | 118.6 | .110.0 | 0.0 | | 153.3 | 0.0 | 0.0 | ŏ | | | 147.6 | | | Begin local hold |
| Enter lunar umbra 57.9 7.8 5.4 -110.0 0.0 0.0 92.9 0.0 156.0 - 156.0 - 156.0 156.0 1 1 | 85:37:06 | Acquire MSFN line of sight | 58.8 | -11.9 | 118.3 | .110.0 | 0.0 | | 153.6 | 0.0 | 0.0 | | | 126.3 | 167.5 | | | Continue local hold |
| Roll 180 degi pitch 57.5 deg 57.8 8.5 0.8 -52.5 0.0 180.0< | 86:14:30 | Enter lunar umbra | 57.9 | 7.8 | 5.4 | - 110.0 | 0.0 | 0.0 | 92.9 | 0.0 | 0.0 | | 67.0 | No line of sight | eight | | | Continue local hold |
| Begin DAU realignment 57.9 12.3 -42.4 -10.0 0.0 180.0 145.9 0.0 180.0 150.4 Lose MSFN line of sight 58.4 6.8 -102.7 49.5 0.0 146.9 0.0 180.0 0.0 180.0 No line on line on line on line on line on line on line of sight 58.4 6.6 -104.0 -45.0 0.0 180.0 50.1 0.0 180.0 No line on line on line on line of sight 58.7 0.1 -135.7 -45.0 0.0 180.0 17.9 0.0 180.0 | 86:16:00 | Roll 180 deg; pitch 57, 5 deg | 57.8 | 8.5 | 9.0 | - 52.5 | | 180.0 | 145.9 | | 180.0 | | 9.69 | No line of sight | sight | | | Begin inertial hold |
| Lose MSFN line of sight 58.4 6.8 -102.7 49.5 0.0 180.0 145.9 0.0 180.0 No line of Maneuver to lunar observation attitude 58.4 6.6 -104.0 -45.0 0.0 180.0 50.1 0.0 180.0 No line of Enter sunlight 58.7 0.1 -135.7 -45.0 0.0 180.0 17.9 0.0 180.0 No line of Acquire MSFN line of sight 58.8 -11.8 117.9 -45.0 0.0 180.0 -87.8 0.0 180.0 25.1 | 86:30:00 | Begin DMU realignment | 57.9 | 12.3 | -42.4 | - 10,0 | 0.0 | 180.0 | 145.9 | | 180.0 | 150.4 | 69.5 | No line of sight | eight | | | Continue inertial hold |
| Maneuver to lunar observation attitude 58.4 6.6 -104.0 -45.0 0.0 180.0 50.1 0.0 180.0 No line of Enter sunlight Acquire MGFN line of sight 58.8 -11.8 117.9 -45.0 0.0 180.0 -87.8 0.0 180.0 25.1 | 86:49:35 | Lose MSFN line of sight | 58.4 | 8.9 | - 102, 7 | 49.5 | 0.0 | 180.0 | 145.9 | 0.0 | 180.0 | No line of | sight | No line of sight | • ight | | | Continue inertial hold |
| Enter sunlight 58.7 0.1 -135.7 -45.0 0.0 180.0 17.9 0.0 180.0 No line of Acquire MASFN line of sight 58.8 -11.8 117.9 -45.0 0.0 180.0 -87.8 0.0 180.0 25.1 | 86:50:00 | Maneuver to lunar observation attitude | 58.4 | 9.9 | - 104. 0 | -45.0 | | 180.0 | 50.1 | | 180.0 | No line of | eight | - | sight | | | Begin local hold |
| Acquire MSFN line of sight 58.8 -11.8 117.9 -45.0 0.0 180.0 -87.8 0.0 180.0 25.1 | 87:00:37 | Enter sunlight | 58.7 | 0.1 | -135.7 | -45.0 | | 180.0 | 17.9 | | 0.081 | No line of | sight | 27.1 | - 157, 1 | | | Continue local hold |
| | 87:35:27 | Acquire MSFN line of sight | 58.8 | -11.8 | 117.9 | -45.0 | 0.0 | 180.0 | -87.8 | 0.0 | 180.0 | | 67.8 | 130.1 1 | -166.7 | | | Continue local hold |
| | 87:53:00 | Terminate local attitude hold | 58.3 | -4.5 | 64. 5 | -45.0 | | 180.0 | 141.0 | | 180.0 | | | . 1.691 | -68.0 | | | Begin inertial hold |
| | 90.13.05 | Ester luner numbre: begin IMI realignme | ent 57.9 | 7.7 | 4.7 | 15.7 | | | 141.0 | | 180.0 | ıc. | 74.8 | No line of sight | sight | | | Continue inertial hold |

Table II. Spacecraft Attitude Data (c) Lunar Orbit (Continued)

| | Comment | Triple in the state of the stat | Continue mertial hold | Continue inertial hold | Continue inertial hold |
|---------------------------|----------------------------------|--|-------------------------------|------------------------|------------------------|
| Look Angles | Theta Phi (deg) (deg) | | | | |
| Look Angles | Theta Phi (deg) (deg) | | No line of sight | 9.6 -97.0 | 9.6 -97.0 |
| Look Angles To Earth | Theta Phi (deg) (deg) | ~ | No line of sight | No line of sight | No line of eight |
| IMU Gimbal Angles | IGA MGA OGA (deg) (deg) (deg) | -141.0 0.0 180.0 | 42.0 0.6 179.9 | 42.0 0.6 179.9 | 42.0 0.6 179.9 |
| Local Horizontal Attitude | (deg) (deg) (deg) | 121.7 0.0 180.0 - | -48.9 0.6 -179.9 | -21.0 0.6 -179.9 | -6.3 0.6 -179.9 |
| hic Position | tude Longitude | 0 -103.0 1 | 8 -109.2 | -136,7 | 0 -151.0 |
| Selenograp | Altitude Lati | 58.4 7. | 58.5 5. | | 58.8 -3.0 |
| | Event | Lose MSFN line of sight | Maneuver to TEI burn attitude | Inter sunight | |
| Mission | (hr:min:ecc) | 88:47:53 | 88:50:00 | 89:04:02 | |

Table II. Spacecraft Attitude Data (d) Transearth

| No. 1975 Text contact cont | | | Georg | Geocentric Inertial | tial | Z | DMU Gimbal | | Look Angles | gles | Look Angles | ngles | Look Angles | ngles | |
|--|--------------|--|--------|---------------------|--------|--------|----------------|---------------|-------------|---------|-------------|--------|-------------|--------|---|
| THE could the DRU alignment of the complete body alignment of | Mission Time | D) (Anna | 1 | Y aw | Roll | | Apgles MCA | V (30) | Theta | # G | Theta | Phi | Theta | Phi | Comments |
| TEX consists artifation attituings: orient for artifation attituings: orie | 722 | | | | | | 1 | T S | 1 | Mani | 1 | | 1 | 140 | |
| Orient for DMI digement 174,6 0.1 57.0 52.5 0.1 179.7 11.1 26.6 95.5 9.0 95.5 170.0 | 89:06:53 | TEI cutoff | -174.6 | 0.1 | 57.0 | -52.5 | 0.1 | -179.7 | No line o | f sight | 0.0 | -177.8 | 95.6 | -170.0 | Acquire lunar surface in window, inertial hold |
| Complete bard bilgments orient for navigation sightings 114,6 0.1 57,0 -22,5 0.1 179,7 11,2 26,4 0.5,6 0.5,7 170,0 Perform BLL avargation sightings 141,1 44,0 193,8 105,3 2,4 42,7 10,0 45,4 177,0 148,1 18,0 Complete avargation sightings 141,2 44,0 193,8 105,3 2,4 42,7 0.0 54,4 177,0 148,1 18,0 Camplete avargation sightings 141,2 44,0 193,8 105,3 12,4 42,7 0.0 45,4 177,0 148,1 18,0 Camplete avargation sightings 142,2 35,3 145,2 143,1 12,2 44,1 10,2 42,7 10,0 15,1 13,1 Camplete PTC orient for avargation sightings 124,2 35,3 145,2 142,0 124,2 35,3 145,2 142,0 143,1 12,2 144,1 12,2 144,1 12,2 144,1 12,2 144,1 12,2 144,1 12,2 144,1 12,2 144,1 144, | 90:00:00 | Orient for IMU alignment | -174.6 | 0.1 | 57.0 | -52.5 | 0.1 | -179.7 | 11.1 | 56.6 | 95.5 | 0.0 | 92.6 | -170.0 | 0.5 deg/sec maneuver rate |
| Complete MV Lilgament; orient for navigation 1914.6 0.1 57.0 -52.5 0.1 -179.7 11.2 26.4 105.5 0.0 95.7 -170.0 14.1 14.1 14.0 -119.8 -105.7 -2.9 -4.1 42.8 0.0 95.8 -177.6 148.0 18.8 14.0 19.8 14.0 19.8 14.0 19.8 14.0 19.8 14.0 19.8 14.0 19.8 14.0 19.8 14.0 19.8 14.0 19.8 14.0 19.8 14.1 19.8 14.0 19.8 14.1 19.8 14.0 19.8 14.1 19.8 18.1 19.8 18.1 19.8 18.1 | 90:10:00 | Perform IMU alignment | -174.6 | 0.1 | 57.0 | -52.5 | 0.1 | -179.7 | 11.2 | 26.5 | 9.66 | 0.0 | 95.7 | -170.0 | Continue inertial hold |
| Perform SLL navigation sightings 141, 3 44, 0 119, 8 110, 3 2, 9 4, 1 4, 2 6, 0 6, 14, 1 11, 10 14, 1 11, 1 14, 1 11, 10 14, 1 11, 10 14, 1 11, 10 14, 1 11, 10 14, 1 11, 10 14, 1 11, 10 14, 1 11, 10 14, 1 11, 10 14, 1 11, 10 14, 1 11, 10 14, 1 11, 10 14, 1 11, 10 14, 1 11, 10 14, 1 11, 10 14, 1 11, 10 14, 1 11, 10 14, 1 11, 10 14, 1 11, 10 14, 1 11, | 90:30:00 | Complete IMU alignment; orient for navigation sightings | -174.6 | 0.1 | 57.0 | -52,5 | 0, 1 | -179.7 | 11.2 | 26.4 | 105.5 | 0.0 | 95.7 | -170.0 | 0. 5 deg/sec maneuver rate |
| Complete navigation sightings: orient for PTC -141.3 44.0 -1194.9 -105.3 -2.9 -4.1 42.7 -0.0 6.3.4 -1177.0 148.1 18.8 6 start PTC complete navigation sightings: orient for partial complete DTC complete DTC complete DTC complete navigation sightings: orient for partial complete DTC complete navigation sightings: orient for partial complete DTC complete DTC complete navigation sightings: orient for partial complete navigation sightings: orient for partial complete DTC complete navigation sightings: orient for partial complete DTC compl | 90:40:00 | Perform SLL navigation sightings | -141,3 | 4.0 | -139.8 | -105,3 | -2.9 | 7. | 42.8 | 0.0 | 54.8 | -177.6 | 148.0 | 18.8 | Begin inertial hold |
| Complete PTC; orient for avaygation sightings 81,2 66,3 144,8 41,4 10.2 47,1 106,6 135,0 131,0 13,1 | 92:00:00 | Complete navigation sightings; orient for PTC | -141.3 | 44.0 | -139.8 | -105,3 | -2.9 | -4.1 | 42.7 | 0.0 | 63.4 | -177.0 | 148.1 | 18.8 | 0.5 deg/sec maneuver rate |
| Complete PTC; orient for navigation nightings St. 10.0 166.4 90.1 29.4 55.9 19.6 11.0 19.1 1 | 92:15:00 | Start PTC tumble mode | 81.2 | -66,3 | -144.8 | 43.4 | 10.2 | 47.1 | 106.6 | 135.0 | 145.1 | -32.7 | 0.0 | -53.7 | Yaw at 0.2 deg/sec |
| Complete antigation sightings: orient for Perform SLH anvigation sightings: orient for T. 124.2 55.3 -150.5 -121.0 -4.8 -2.7 58.4 0.0 57.5 180.0 15.3 23.1 Complete antigation sightings: orient for T. 124.2 55.3 -150.5 -121.0 -4.8 -2.7 58.4 0.0 58.5 -179.9 15.3 23.1 Complete antigation sightings: orient for T. 124.2 55.3 -150.5 -121.0 -4.8 -2.7 58.4 0.0 58.5 -179.9 15.3 23.1 Complete antigation sightings: orient for T. 124.2 55.3 -150.5 -121.0 -4.8 -2.7 58.4 0.0 58.5 -179.9 15.3 23.1 Complete antigation sightings: orient for PTC 55.3 -150.5 -121.0 -4.8 -2.7 58.4 0.0 58.5 -179.9 15.3 23.1 Complete antigation sightings: orient for PTC 55.3 -150.5 -121.0 -4.8 -2.7 58.4 0.0 58.5 -179.9 15.3 23.1 Complete antigation sightings: orient for PTC 55.3 -150.5 -121.0 -4.8 -1.4 -4.8 57.5 180.0 174.6 -157.0 49.6 9.8 Start PTC Complete antigation sightings orient for PTC 55.3 -150.5 -120.6 -4.6 -127.7 58.4 0.0 58.7 -179.9 15.3 -1.5 Complete antigation sightings: orient for PTC 55.3 -150.5 -120.6 -4.6 -127.7 58.4 0.0 58.7 -150.0 -0.0 Start PTC Complete antigation sightings orient for PTC 5.3 -1.6 -1.4 -4.8 -1.4 -4.8 -1.7 -1. | 97:10:00 | Complete PTC; orient for navigation sightings | 50,7 | -10.0 | -166.4 | 90.1 | -29.4 | 55.9 | 136.8 | 172.1 | 91.2 | -56.9 | 6.65 | 89.8 | 0.5 deg/sec maneuver rate |
| Complete navigation sightings: orient for 124,2 55,3 120,5 121,0 -4,8 -2,7 58,4 0.0 57,9 180,0 183,9 23.1 Complete DU alignment 1124,2 55,3 150,5 121,0 -4,8 -2,7 58,4 0.0 58,2 179,9 153,9 23.1 Complete DU alignment 1124,2 55,3 150,5 121,0 -4,8 -2,7 58,4 0.0 58,2 179,9 153,9 23.1 Orient for avergation sightings 124,2 55,3 150,5 121,0 -4,8 -2,7 58,5 0.0 58,7 179,9 153,9 23.1 Complete DUC complete PCC: orient for avergation sightings 124,2 55,3 150,5 121,0 -4,8 -2,7 58,5 0.0 58,7 179,9 153,9 23.2 Complete PCC: orient for avergation sightings 124,2 130,1 130,1 -4,8 -1,4 165,6 110,0 111,0 64,2 140,9 9.8 Complete avergation sightings 124,2 130,1 130,1 14,8 11,4 165,6 110,0 111,0 64,2 140,9 9.8 Complete avergation sightings 124,2 130,1 130,1 14,8 11,4 165,6 110,0 11,4 165,6 110,0 11,4 165,6 110,0 11,4 165,6 110,0 11,4 165,6 110,0 11,4 165,6 110,0 11,4 165,6 110,0 11,4 165,6 110,0 11,4 165,6 110,0 11,4 165,6 110,0 11,4 165,6 110,0 11,4 11,4 165,6 110,0 11,4 | 97:20:00 | Perform SLH navigation sightings | -124.2 | 55.3 | -150.5 | -121.0 | -4.8 | -2.7 | 58,3 | 0.0 | 57.5 | 180.0 | 163.9 | 23.1 | Begin inertial hold |
| Complete marigation sightings: orient for PTC: 55.3 -150.5 -121.0 -4.8 -2.7 58.4 0.0 58.0 -179, 9 163.9 23.1 formable decourse correction Orient for navigation sightings: orient for PTC: 55.3 -150.5 -121.0 -4.8 -2.7 58.5 0.0 58.2 -179, 9 163.9 23.2 formalize middle marigation sightings orient for pavigation sightings: orient for pavigation sightings: orient for pavigation sightings: orient for pavigation sightings: orient for PTC: 51.3 -1.37 1 -130.1 -4.8 -1.4 4.8 57.5 180.0 174.6 -167.0 49.6 9.8 Complete navigation sightings: orient for PTC: 51.3 -4.4 -60.2 120.6 -4.4 165.6 130.7 111.3 64.9 11.3 64.0 11.3 64.9 11. | 98:00:00 | Complete navigation sightings; orient for IMU alignment | -124.2 | 55.3 | -150.5 | -121.0 | -4.8 | -2.7 | 58.4 | 0.0 | 57.9 | 180,0 | 163.9 | 23. 1 | 0.5 deg/sec maneuver rate |
| Complete BUU alignment 124, 2 55, 3 150, 5 121, 0 -4, 8 -2, 7 58, 4 0, 0 58, 2 179, 9 163, 9 23, 1 Orient for arvigation sightings 124, 2 51, 130, 1 130, 1 14, 8 17, 130, 1 14, 8 17, 5 180, 0 174, 110, 110, 1 14, 8 17, 5 180, 0 174, 110, 1 17, | 96:10:00 | Perform IMU alignment | -124.2 | 55, 3 | -150,5 | -121.0 | -4.8 | -2.7 | 58.4 | 0.0 | 58.0 | -179.9 | 163.9 | 23.1 | Continue inertial hold |
| Diritate midcourse correction 124,2 55,3 150,5 121,0 -4,8 7.2,7 58,5 0.0 58,5 179,9 163,9 23,2 124,2 124,2 55,3 150,5 121,0 -4,8 7.2,7 58,5 0.0 58,7 179,9 163,9 23,2 124,2 124,2 55,3 150,5 121,0 -4,8 7.2,7 58,5 0.0 58,7 179,9 163,9 123,2 124,2 12 | 98:30:00 | Complete DAU alignment | -124.2 | 55.3 | -150.5 | -121.0 | .4. | -2.7 | 58.4 | 0.0 | 58.2 | -179.9 | 163.9 | 23.1 | Continue inertial hold |
| Orient for navigation sightings Orient for navigation sightings Orient for navigation sightings Orient for navigation sightings Ormplete party or navigation sightings Occupiete navigation sightings Occupied navigation s | 99:00:00 | Initiate midcourse correction | -124,2 | 55, 3 | -150.5 | -121.0 | - 4 . 8 | -2.7 | 58.5 | 0.0 | | -179.9 | 163.9 | 23.2 | Continue inertial hold |
| Complete navigation sightings: orient for PTC 153.1 -137.1 -130.1 -4.8 -1.4 4.8 57.5 180.0 174.6 -167.0 49.6 9.8 12.0 Cumplete navigation sightings: orient for PTC 153.1 -137.1 -130.1 -4.8 -1.4 4.8 57.5 180.0 174.9 -165.9 49.6 9.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 | 99:10:00 | Orient for navigation sightings | -124.2 | 55, 3 | -150,5 | -121.0 | . . | -2.7 | 58.5 | 0.0 | 58.7 | -179.9 | 163.9 | 23.2 | 0.5 deg/sec maneuver rate |
| Complete navigation sightings: orient for PTC 45,9 19,9 -76,8 123,6 -44,3 165,6 130,6 112,0 66,5 -140,9 90,0 0.0 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 | 99:20:00 | Perform SEH navigation sightings | 153, 1 | -37.1 | -130,1 | -4.8 | -1.4 | 4 .8 | 57.5 | 180,0 | 174.6 | -167.0 | 49.6 | 9.8 | Begin inertial hold |
| Start PTC Complete PTC; orient for navigation sightings 45.9 19.9 10.9 10.9 10.9 10.9 10.10 1 | 99:50:00 | Complete navigation sightings; orient for PTC | 153.1 | -37.1 | -130.1 | 4.8 | +1.+ | 4 .8 | 57.5 | 180.0 | 174.9 | -165,9 | 49.6 | 9.8 | 0.5 des/sec maneuver rate |
| Complete PTC: orient for navigation sightings 5.3 -8.4 -6.0.2 120.6 -4.6 176.7 177.7 179.9 57.5 180.0 75.9 -6.1 1.2 1.2 1.2 1.2 1.2 1.2 1.2 1.2 1.2 1 | 100:06:00 | Start PTC | 45.9 | 19.9 | -76.8 | 123.6 | -44.3 | 165.6 | 130,6 | 112.0 | | -140.9 | 90.0 | 0.0 | Roll at 0, 2 deg/sec |
| Complete navigation sightings orient for PTC 5.3 -8.4 -60.2 120.6 4.6 176.7 177.8 180.0 57.5 180.0 76.1 -6.2 54 58 20.1 -77.0 123.8 -44.3 165.6 130.7 111.6 64.9 138.8 90.0 0.0 57.5 58 20.1 -77.0 123.8 -44.3 165.6 130.7 111.6 64.9 138.8 90.0 0.0 57.5 58 20.1 -77.0 123.8 -44.3 165.6 130.7 111.6 64.9 138.8 90.0 0.0 57.5 58 20.1 -77.0 123.8 -44.3 165.6 130.7 111.6 64.9 138.8 90.0 0.0 50.0 57.5 58 20.1 -77.0 123.8 -44.3 165.6 130.7 111.6 64.9 138.8 90.0 0.0 50.0 50.0 50.0 50.0 50.0 50.0 | 106:10:00 | Complete PTC; orient for navigation sightings | 45.9 | 19.9 | -76.8 | 123,6 | -44.3 | 165.6 | 130,7 | 111.3 | | -139.3 | 89.8 | -0.2 | 0.5 deg/sec maneuver rate |
| Complete navigation sightings: orient for PTC 5.3 -8.4 -60.2 120.6 4.6 176.7 177.8 180.0 57.5 180.0 75.9 -6.1 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 | 106:20:00 | Perform SLH navigation sightings | 5.3 | -8.4 | -60,2 | 120.6 | 4.6 | 176.7 | 177.7 | 179.9 | 57.5 | 180.0 | 16.1 | -6.2 | Begin inertial bold |
| Start PTC Complete PTC; orient for navigation sightings 45.8 20.1 -17.0 123.8 -44.3 105.6 130.7 111.6 64.9 -138.8 90.0 0.0 Complete PTC; orient for navigation sightings 6.3 -10.1 -60.2 118.7 4.7 176.7 179.3 0.0 57.5 180.0 73.8 -6.1 Derform SLH navigation sightings: orient for 6.3 -10.1 -60.2 118.7 4.7 176.7 179.0 0.0 57.9 180.0 73.8 -6.1 Complete navigation sightings: orient for 6.3 -10.1 -60.2 118.7 4.7 176.7 179.0 0.0 58.0 180.0 73.8 -6.1 Derform SLH navigation sightings: orient for 6.3 -10.1 -60.2 118.7 4.7 176.7 179.0 0.0 58.0 180.0 73.8 -6.1 Derform SLH navigation sightings: orient for 70.1 -60.2 118.7 4.7 176.7 179.0 0.0 58.1 180.0 73.7 6.1 Derform SLH navigation sightings: orient for 70.1 -60.2 118.7 4.7 176.7 179.0 0.0 58.1 180.0 73.7 6.1 Derform SLH navigation sightings: orient for 70.1 -60.2 118.7 4.7 176.7 179.0 0.0 58.1 180.0 73.7 6.1 Derform SLH navigation sightings: orient for 70.1 -60.2 118.7 4.7 176.7 179.0 0.0 58.1 180.0 73.7 6.1 Complete navigation sightings: orient for 70.1 -60.2 118.7 4.7 176.7 179.0 0.0 58.4 180.0 73.7 6.1 Complete navigation sightings: orient for 70.1 -60.2 118.7 4.7 176.7 179.9 0.0 58.4 180.0 73.7 6.1 Complete DATC: extent for navigation sightings: orient for 70.1 170.1 170.7 170.9 170.0 0.0 58.4 180.0 66.1 0.0 162.2 160.4 Sast PTC Sast PTC Complete DATC: extent for navigation sightings: orient for 70.7 170.7 170.7 170.9 170.7 170.9 170.0 0.0 162.2 160.4 Sast PTC Sast PTC Complete DATC: extent for navigation sightings: orient for 70.7 170.7 170.7 170.9 170.9 170.7 170.9 170.7 170.9 170.7 17 | 106:50:00 | Complete navigation sightings; orient for PTC | 5,3 | +8.4 | -60.2 | 120.6 | 4.6 | 176.7 | 177.8 | 180.0 | 57.5 | 180.0 | 75.9 | -6.1 | 0.5 deg/sec maneuver rate |
| Complete PTC; orient for navigation sightings 6.3 -10.1 -137.0 123.8 -44.3 105.6 130.9 170.2 63.9 -77.3 89.8 89.7 Perform SLH navigation sightings orient for PCC 5.3 -10.1 -60.2 118.7 4.7 176.7 179.0 0.0 57.9 180.0 73.8 -6.1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 | 107:05:00 | Start PTC | 45.8 | 20.1 | -77.0 | 123.8 | -44.3 | 165.6 | 130, 7 | 111.6 | | -138.8 | 90.0 | 0.0 | Roll at 0, 2 deg/sec |
| Complete navigation sightings: orient for PTC 6.3 -10.1 -60.2 118.7 4.7 176.7 179.9 0.0 57.9 180.0 73.8 -6.1 DAU alignment DAU alignment Complete InfU alignment Complete InfU alignment DAU alignment DAU alignment Complete InfU alignment Complete InfO alignment DAU alignment Complete InfO alignment InfO alignment Complete InfO alignment | 116:00:00 | Complete PTC; orient for navigation sightings | 45.8 | 20.1 | -137.0 | 123.8 | -44.3 | 105.6 | 130.9 | 170.2 | 63.9 | -77.3 | 89.8 | 59.7 | 0.5 deg/sec maneuver rate |
| Complete navigations eightings: orient for Land Land Land Land Land Land Land Land | 116:10:00 | Perform SLH navigation sightings | 6.3 | -10.1 | - 60.2 | 118.7 | 4.7 | 176.7 | 179,3 | 0.0 | 57.5 | 180.0 | 73.8 | -6.1 | Begin inertial hold |
| Perform DdV alignment 6.3 -10.1 -60.2 118.7 4.7 176.7 179.0 0.0 58.0 180.0 73.8 -6.1 Complete DdV alignment 6.3 10.1 -60.2 118.7 4.7 176.7 179.0 0.0 58.1 180.0 73.7 6.1 Driest Cornection 6.3 10.1 -60.2 118.7 4.7 176.7 178.9 0.0 58.3 180.0 73.7 6.1 Orient for mavigation sightings -6.2 118.7 4.7 176.7 179.9 0.0 58.4 180.0 73.7 6.1 Complete mavigation sightings: orient for PTC -128.5 54.1 33.4 -118.3 -5.2 177.9 57.9 180.0 66.1 0.0 46.2 -160.4 Complete mavigation sightings: orient for PTC 17.3 124.3 -44.4 165.5 110.3 65.1 10.0 66.1 0.0 66.1 0.0 66.1 0.0 66.1 0.0 66.1 <t< th=""><th>117:00:00</th><th>Complete navigation sightings; orient for DdU alignment</th><td>6.3</td><td>-10,1</td><td>-60.2</td><td>118.7</td><td>4.7</td><td>176.7</td><td>179.0</td><td>0.0</td><td>67.9</td><td>180.0</td><td>73.8</td><td>-6.1</td><td>0.5 deg/sec maneuver rate</td></t<> | 117:00:00 | Complete navigation sightings; orient for DdU alignment | 6.3 | -10,1 | -60.2 | 118.7 | 4.7 | 176.7 | 179.0 | 0.0 | 67.9 | 180.0 | 73.8 | -6.1 | 0.5 deg/sec maneuver rate |
| Complete DrU alignment 6.3 10.1 -60.2 118.7 4.7 176.7 176.7 176.9 0.0 58.1 180.0 73.7 6.1 Initiate midcourse correction 6.3 10.1 -60.2 118.7 4.7 176.7 178.9 0.0 58.3 180.0 73.7 6.1 Orient for navigation sightings -128.5 54.1 33.4 -118.3 -5.2 177.9 57.8 180.0 66.1 0.0 152.2 -160.4 Complete navigation sightings: orient for PTC -128.5 54.1 33.4 -118.3 -5.2 177.9 57.8 180.0 66.1 0.0 162.2 -160.4 Complete navigation sightings: orient for PTC -128.5 54.1 33.4 -118.3 -5.2 177.9 57.9 180.0 66.1 0.0 160.4 Sast PTC 45.7 20.4 -77.3 124.3 -44.4 -16.5 110.9 110.3 63.3 130.7 60.0 Complete pravigation sighti | 117:10:00 | Perform DaU alignment | 6.3 | -10.1 | -60.2 | 118.7 | 4.7 | 176.7 | 179.0 | 0.0 | 58.0 | 180.0 | 73.8 | -6.1 | Continue inertial hold |
| Initiate midcourse correction 6.3 10.1 -60.2 118.7 4.7 176.7 178.9 0.0 58.3 180.0 73.7 6.1 Orient for navigation sightings 6.3 10.1 -60.2 118.7 4.7 176.7 179.9 0.0 58.4 180.0 73.7 6.1 Perform SEH navigation sightings orient for PTC -128.5 54.1 33.4 -118.3 -5.2 177.9 57.9 180.0 66.2 0.0 162.2 -160.4 Saar PTC | 117:30:00 | Complete DAU alignment | 6.3 | 10.1 | -60.2 | 118.7 | 4.7 | 176.7 | 179.0 | 0.0 | 58.1 | 180.0 | 73.7 | 6.1 | Continue inertial hold |
| Orient for navigation sightings 6.3 10.1 -60.2 118.7 4.7 176.7 179.9 0.0 58.4 180.0 73.7 6.1 Perform SEH navigation sightings -128.5 54.1 33.4 -118.3 -5.2 177.9 57.8 180.0 66.1 0.0 162.2 -160.4 Complete navigation sightings orient for PTC -128.5 54.1 33.4 -118.3 -5.2 177.9 57.9 180.0 66.2 0.0 162.2 -160.4 Start PTC | 118:00:00 | Initiate midcourse correction | 6.3 | 10.1 | -60.2 | 118.7 | 4.7 | 176.7 | 178.9 | 0.0 | 58.3 | 180.0 | 73.7 | 6.1 | Continue inertial hold |
| Perform SEH navigation sightings -128.5 54.1 33.4 -118.3 ,-5.2 177.9 57.8 180.0 66.1 0.0 162.2 -160.4 Complete navigation sightings: orient for PTC -128.5 54.1 33.4 -118.3 -5.2 177.9 57.9 180.0 66.2 0.0 162.2 -160.4 Start PTC | 118:10:00 | Orient for navigation sightings | 6,3 | 10.1 | -60.2 | 118.7 | 4.7 | 176.7 | 179.9 | 0.0 | 58.4 | 180.0 | 73.7 | 6.1 | 0.5 deg/sec maneuver rate |
| Complete navigation sightings; orient for PTC -128.5 54.1 33.4 -118.3 -5.2 177.9 57.9 180.0 66.2 0.0 162.2 -160.4 Start PTC 45.7 20.4 -77.3 124.3 -44.4 165.5 130.9 110.3 63.3 -136.4 90.0 0.0 Complete PTC; orient for navigation sightings 45.7 20.4 -77.3 124.3 -44.4 -74.5 131.2 -11.7 62.3 105.2 89.7 -120.3 | 118:20:00 | Perform SEH navigation sightings | -128.5 | 54. 1 | 33.4 | -118.3 | -5.2 | 177.9 | 8.75 | 180.0 | 66. 1 | 0.0 | 162.2 | -160,4 | Begin inertial hold |
| Start PTC 54.4 165.5 130.9 110.3 63.3 -136.4 90.0 0.0 0.0 Complete PTC; exiemt for navigation sightings 45.7 20.4 -77.3 124.3 -44.4 -74.5 131.2 -11.7 62.3 105.2 89.7 -120.3 | 118:50:00 | Complete navigation sightings; orient for PTC | -128.5 | 54. 1 | 33.4 | -118.3 | -5.2 | 177.9 | 57.9 | 180.0 | 66.2 | 0.0 | 162.2 | -160.4 | 0.5 deg/sec maneuver rate |
| Complete PTC; exient for navigation sightings 45,7 20,4 -77,3 124,3 -44,4 -74,5 131,2 -11,7 62,3 105,2 89,7 -120,3 | 119:05:00 | Start PTC | 45.7 | 20.4 | -77.3 | 124.3 | -44.4 | 165.5 | 130.9 | 110.3 | | -136.4 | 90.0 | 0.0 | Roll at 0, 2 deg/sec |
| | 128:50:00 | Complete PTC; exient for navigation sightings | 45.7 | 20.4 | -77.3 | 124.3 | -44.4 | -74.5 | 131.2 | -11.7 | 62.3 | 105.2 | 89.7 | -120,3 | 0.5 deg/sec maneuver rate |

Table II. Spacecraft Attitude Data (d) Transearth (Continued)

| Perform SEH avaigation sightings Perform PERform SEH avaigation sightings Perform SEH avaigation sightings Perfor |] | | to Earth | to Moon Theta | yon Phi | Sun | į | |
|--|------------|----------|----------|------------------|--------------------|-----------|--|--|
| Complete anxigation sightings Complete anxigation sighting | | | *** | | - | | Ē | |
| Complete navigation sightings 141,4 12,5 143,7 0.6 11,2 1.6 57,7 11,1 Perform SLH anvigation sightings 141,4 12,5 143,7 0.6 11,2 1.6 57,7 11,1 Perform SLH anvigation sightings 1,5 1,5 1,5 1,5 1,5 1,5 1,4 1,7 1,6 1,4 1,7 1,6 1,4 1,4 1,5 1,4 1,4 1,5 1,4 1, | | | (deg.) | (deg) | (deg) | | ٠ | Comments |
| Complete anvigation sightings: orient for SLH 141, 4 -12, 5 -14, 1 -16, 0 116, 4 -17, 176, 9 174, 9 Perform SLH anvigation sightings orient for PTC 7, 5 -12, 1 -60, 0 116, 4 -7 176, 9 174, | | | .7 179.8 | 167.5 | -62.0 | 50.1 | 25.3 Begin | Begin inertial hold |
| Complete navigation sightings 7.5 12.1 -60.0 116.4 4.7 176.9 174.9 Complete navigation sightings 2.5 12.2 -60.0 116.4 4.7 176.9 174.9 Perform SLH avargation sightings 2.5 12.2 -60.0 116.4 4.7 176.9 174.9 Perform SLH avargation sightings 2.5 12.2 -60.0 116.4 4.7 177.2 170.3 Perform SLH avargation sightings 2.5 12.3 20.7 177.6 124.8 4.4 177.2 170.3 Perform MU digement 8.8 -13.9 -99.6 114.1 4.7 177.2 170.0 Perform SLH avargation sightings 8.8 -13.9 -99.6 114.1 4.7 177.2 170.0 Orient for avargation sightings 8.8 -13.9 -99.6 114.1 4.7 177.2 170.0 Perform SEH avargation sightings 8.8 -13.9 -99.6 114.1 4.7 177.2 170.0 Perform SEH avargation sightings 8.8 -13.9 -99.6 114.1 4.7 177.2 170.0 Perform SEH avargation sightings 8.8 -13.9 -99.6 114.1 4.7 177.2 170.0 Perform SEH avargation sightings 9.8 -13.9 -99.6 114.1 4.7 177.2 199.8 Complete avargation sightings 9.8 -13.9 -13.9 -13.6 -13.1 -13.6 -13.1 -13.8 -13.1 -13.8 -13.1 -13.8 -13.1 -13.8 -13.1 -13.8 -13.1 -13.8 -13.1 -13.8 -13.1 -13.8 -13.8 -13.1 -13.8 -13.8 -13.1 -13.8 -13.8 -13.8 -13.2 -13.8 -13.2 -13.8 -13. | | | 7. 179.7 | 167.5 | -61.6 | 50,2 | 25.3 0.5 de | 0.5 deg/sec maneuver rate |
| Complete navigation nightings: orient for PTC 45, 3 20,7 -77, 6 124, 44,7 176, 5 114, 100 Complete navigation nightings orient for pTC 113, 9 -59, 6 114, 1 4,7 177, 2 169, 9 - 113, 9 - 11 | | | 8 0.0 | 57, 5 | 180.0 | 70.9 | -6.2 Begin | Begin inertial hold |
| Sart PTC Complete artigation sightings Complete artigation sightings Complete artigation sightings: orient for mayigation sightings Complete artigation sightings: orient for mayigation sightings Complete artigation sightings Complete bTC; orient for artigation sightings Complete artigation sightings Complete artigation sightings Complete bTC; orient for bUU vicentation Complete bUU vicentation | | | | | | | | ! |
| Complete PTC; orient for mavigation sightings (45.3) 20.7 - 17.6 (124.8) - 144.2 - 114.5 (17.2) 131.7 (10.0) 140.0 sightings orient for Multiplement (17.2) 12.9 (14.1) 17.2 (17.2) 17.0 (| , | | ; | 0.50 | 180.0 | 6.0 | | 0.5 deg/sec maneuver rate |
| Complete navigation sightings: orient for this state of the state of | -44. | | • | 7 7 7 | -154.1 | | | Roll at 0.2 deg/sec |
| Decemblete navigation sightings; orient for the form DAU alignment | · · · | | | 57.5 | 180.0 | . 2.89 | -60,4 Beain | 5 deg/sec maneuver rate Begin inertial hold |
| Device that Device Devic | 4.7 | | 0.0 | 57.3 | 180.0 | | | 0. 5 deg/sec maneuver rate |
| Complete DMC alignment 8.8 -13.9 -59.6 114.1 4.7 177.2 169.9 -19.0 | 4.7 | | | 57.3 | 0 081 | . 07 | | : |
| Designate mid-course correction 8.8 -13.9 -59.6 114.1 4.7 177.2 169.8 14.1 4.7 177.2 169.8 14.1 4.7 177.2 169.8 14.1 4.7 177.2 169.8 14.1 177.2 169.8 14.1 177.2 169.8 177.2 1 | 4.7 | | , | | 2.00 | | | Continue inertial hold |
| Complete navigation sightings Complete DAC orient and perform SLL Complete navigation sightings Complete DAC orient and perform SLL Complete DAC orient and perform sightings Complete DAC orient | 4.7 | | | : : | | | | Continue inertial hold |
| Complete navigation sightings -134,6 51,2 38,3 -113,5 -5,2 178,4 57,8 | 4.7 | | | 2.2 | 200 | | -0.4 Contin | Continue mertial hold |
| Complete navigation sightings; orient for PTC -134,6 51.2 38.3 -113.5 -5.2 178,4 57.9 51.8 51.4 Ferform SEH navigation sightings 45.0 21.0 -77.9 125.4 -44.1 165.5 132.0 Complete PTC; orient for navigation sightings orient for PTC 133.1 -28.8 -154.4 3.2 -18.3 -7.0 55.8 51.1 Complete DTC; orient for navigation sightings orient for PTC 133.1 -28.8 -154.4 3.2 -18.3 -7.0 55.8 51.1 102.0 125.7 -44.0 165.5 133.2 Complete navigation sightings orient for PTC 133.1 -28.8 -154.4 3.2 -18.3 -7.0 56.8 8.3 57.5 Complete navigation sightings orient for PTC 11.8 -18.0 -58.6 109.1 4.5 177.8 158.8 Start PTC Complete navigation sightings; orient for PTC 11.8 -18.0 -58.6 109.1 4.5 177.8 158.8 Start PTC Complete navigation sightings; orient for PTC 11.8 -18.0 -58.6 109.1 4.5 177.8 158.8 Start PTC Complete navigation sightings; orient for PTC 11.8 -18.0 -58.6 109.1 4.5 177.8 158.8 Complete DTC; orient for DMU orientation 135.2 19.2 105.1 -125.7 38.4 175.8 139.9 -1 100.0 10.0 137.4 10.0 10.0 10.0 10.0 10.0 10.0 10.0 10 | -5.2 | | - | 75.6 | 0.0 | ' | F & | 0.5 deg/sec maneuver rate Begin inertial bold |
| Complete PTC; orient for navigation sightings 45,0 21,0 -77,9 125,4 -44,1 165,5 131,8 | | | | 7. 27 | | | | |
| Complete PTC; orient for navigation sightings 45.0 21.0 -42.1 125.4 -44.1 -74.5 122.0 20.0 Derform SEH navigation sightings; orient for PTC 133.1 -28.8 -154.4 3.2 -18.3 -7.0 57.1 58.4 58.4 51.1 102.0 125.7 -44.0 165.5 132.2 Complete PTC; orient for PTC 11.8 -18.0 -58.6 109.1 4.5 177.8 158.8 54.4 FTC Complete navigation sightings orient for PTC 11.8 -18.0 -58.6 109.1 4.5 177.8 158.8 54.4 FTC Complete DTC; orient for IMU alignment 155.2 19.2 105.1 -125.7 38.4 175.8 139.9 -10.0 Complete DMU alignment 172.3 62.4 -14.8 156.0 0.0 0.0 147.1 1 0.0 0.0 147.1 1 0.0 0.0 0.0 173.4 1 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0 | -44- | | | | | | | o. 5 deg/sec maneuver rate |
| Complete mavigation sightings 133.1 -28.8 -154.4 3.2 -18.3 -7.0 57.1 | 7 | | | | 130.9 | 0.00 | | Roll at 0, 2 deg/mec |
| Complete navigation sightings; orient for PTC Start PTC Gentplete PTC; orient for navigation sightings Complete PTC; orient for navigation sightings Review and perform SLL navigation sightings Complete PTC; orient for PTC Complete navigation sightings Complete navigation sightings Complete navigation sightings Complete NTC Complete PTC; orient for DTC Complete NTC Complete PTC; orient for DTC Complete DTC; orient for DTC Complete DTC Complete DTC; orient for DTC Complete DTC Complete DTC; orient for DTC Complete D | , at- | | | 2.65 | | 7 | | 0. 5 deg/sec maneuver rate |
| Complete navigation sightings; orient for PTC 133.1 -28.8 -154.4 3.2 -18.3 -7.0 56.8 | | | _ | 157, 3 | - 4 3.8 | 50.9 | 37.9 Begin | Begin inertial bold |
| Start PTC Complete PTC; orient for navigation sightings 44,8 21,1 102,0 125,7 -44,0 165,5 132,2 Perform SEH navigation sightings 44,8 21,1 102,0 125,7 -44,0 -14,5 132,4 Perform SEH navigation sightings 149,2 -50,8 -128,8 6,7 6,6 8,3 57,5 Reorient and perform SLL | | | | 157.2 | -43,2 | 50.9 | 37.9 0.5 de | 0. 5 des/asc mananver rate |
| Complete PTC; orient for navigation sightings | -44.0 | | | . 9.85 | -128.6 | | | Roll at 0.3 day/acc |
| Recriean SEH navigation sightings 149,2 -50,8 -128,8 6,7 6,6 8,3 57,5 | -44.0 | | | | 53.4 | | | , r 40g/ esc |
| Reorient and perform S.L. 11.8 -18.0 -58.6 109.1 4.5 177.8 158.8 Complete navigation sightings orient for PTC 11.8 -18.0 -58.6 109.1 4.5 177.8 158.5 158.5 158.7 | | | - | 158.8 | 10.6 | | | Begin inertial hold |
| Complete navigation sightings: orient for PTC 11.8 -18.0 -58.6 109.1 4.5 177.8 158.5 54 24.5 7-44.8 165.3 131.6 9 determination orientation determination 35.2 19.2 105.1 -125.7 38.4 175.8 139.9 -10 Complete PTC: orient for DMU orientation determination: 35.2 19.2 105.1 -125.7 38.4 175.8 139.9 -10 Complete DMU sligament 35.2 19.2 105.1 -125.7 38.4 175.8 139.2 -10 Complete DMU alignment 35.2 19.2 105.1 -125.7 38.4 175.8 139.2 -11 Perform DMU alignment 35.2 19.2 105.1 -125.7 38.4 175.8 138.2 -11 Perform DMU alignment 35.2 19.2 105.1 1.25.7 38.4 175.8 138.4 -111 Complete DMU alignment -72.3 62.4 -14.8 156.0 0.0 0.0 137.4 188 Complete DMU sligament -72.3 62.4 -14.8 156.0 0.0 0.0 137.4 188 CM/SM separation 55.3 -2.2 -47.7 -87.3 45.0 0.0 0.0 179.8 -2.2 CM/SM separation 55.3 -2.2 -47.7 -87.3 45.0 0.0 0.0 179.8 -2.2 CM/SM separation 55.3 -2.2 -47.7 -87.3 45.0 0.0 0.0 179.8 -2.2 CM/SM separation 55.3 -2.2 -47.7 -87.3 45.0 0.0 0.0 179.8 -2.2 -2.2 CM/SM separation 55.3 | 4 | | | | | | | |
| Complete navigation sightings; orient for PTC 11.8 -18.0 -58.6 109.1 4.5 177.8 158.5 Ocmplete DTC Ocmplete DTC 45.6 21.5 -78.5 125.7 -44.8 165.3 131.6 9 Ocmplete DTC Ocmplete DWU orientation determination: 35.2 19.2 105.1 -125.7 38.4 175.8 139.9 -10 Ocmplete DWU alignment Derform DAU alignment 35.2 19.2 105.1 -125.7 38.4 175.8 138.9 -11 Perform DAU alignment Derform DAU alignment 35.2 19.2 105.1 -125.7 38.4 175.8 138.2 -11 Perform DAU alignment -72.3 62.4 -14.8 156.0 0.0 0.0 147.1 18 Complete DMU alignment -72.3 62.4 -14.8 156.0 0.0 0.0 147.1 18 Complete DMU alignment -72.3 62.4 -14.8 156.0 0.0 0.0 147.1 18 | ì | | | ٠,٠ | 180.0 | 62.6 | -7.2 Begin i | Begin inertial hold |
| Complete PTC content for IMU orientation 35.2 19.2 105.1 -125.7 -44.8 165.3 131.6 determination 35.2 19.2 105.1 -125.7 38.4 175.8 139.9 -1 orient for IMU alignment 35.2 19.2 105.1 -125.7 38.4 175.8 139.9 -1 orient for IMU alignment 35.2 19.2 105.1 -125.7 38.4 175.8 139.2 -1 Ocmplete DMU alignment 35.2 19.2 105.1 -125.7 38.4 175.8 138.2 -1 Initiate midcourse correction 35.2 19.2 105.1 -125.7 38.4 175.8 138.2 -1 Initiate midcourse correction 35.2 19.2 105.1 -125.7 38.4 175.8 136.4 -1 Orient for CM/SM separation -72.3 62.4 -14.8 156.0 0.0 0.0 177.1 11 Orient for CM/SM separation 55.3 -2.2 -47.7 -87.3 45.0 0.0 6.0 177.1 11 | 4.5 | | | 57, 3 | 180.0 | 62.6 | -7.2 0.5 de | 0.5 dec/aec maneuver rate |
| Complete PTC: orient for IMU orientation 35.2 19.2 105.1 -125.7 38.4 175.8 139.9 -1 orientation determination: 35.2 19.2 105.1 -125.7 38.4 175.8 139.9 -1 orient for DMU alignment 35.2 19.2 105.1 -125.7 38.4 175.8 139.2 -1 Omplete DMU alignment 35.2 19.2 105.1 -125.7 38.4 175.8 138.9 -1 Initiate midcourse correction 35.2 19.2 105.1 -125.7 38.4 175.8 138.2 -1 Initiate midcourse correction 35.2 19.2 105.1 -125.7 38.4 175.8 138.2 -1 Initiate midcourse correction 35.2 19.2 105.1 -125.7 38.4 175.8 138.4 -1 Orient for CM/SM separation -72.3 62.4 -14.8 156.0 0.0 0.0 147.1 11 Orient for CM/SM separation 55.3 -2.2 -47.7 -87.3 45.0 0.0 68.2 | -44.8 | | | - 6.75 | -125.4 | | | Roll at 0.2 deg/eac |
| Complete IMU orientation determination; orient for IMU alignment Perform IMU alignment Complete IMU alignment Complete IMU alignment Determination determination; Social 19, 2 105, 1 -125, 7 38, 4 175, 8 138, 9 -18, 105, 1 -125, 7 38, 4 175, 8 138, 5 -18, 105, 1 -125, 7 38, 4 175, 8 138, 5 -18, 105, 1 -125, 7 38, 4 175, 8 136, 4 -18, 105, 1 -125, 7 38, 4 175, 8 136, 4 -18, 105, 1 -125, 7 38, 4 175, 8 136, 4 -18, 105, 1 -125, 7 38, 4 175, 8 136, 4 -18, 105, 1 -125, 7 38, 4 175, 8 136, 4 -125, 7 38, 4 175, 8 126, 7 126 | 38.4 | | 7 | | 55.6 | = | | Change to entry REFSMMAT, |
| Perform IMU alignment 35.2 19.2 105.1 -125.7 38.4 175.8 138.9 - Complete IMU alignment 35.2 19.2 105.1 -125.7 38.4 175.8 138.2 - Initiate midcourse correction 35.2 19.2 105.1 -125.7 38.4 175.8 138.2 - Perform IMU alignment -72.3 62.4 -14.8 156.0 0.0 0.0 137.4 Complete IMU alignment -72.3 62.4 -14.8 156.0 0.0 0.0 147.1 Orient for CM/SM separation 55.3 -2.2 -47.7 -87.3 45.0 0.0 68.2 | 38.4 | | | 47.1 | 55.9 | 71 17 | 0.5 de ₁ 179.7 0.5 de ₁ | 0.5 deg/sec maneuver rate 0.5 deg/sec maneuver rate |
| Complete IMU alignment 35.2 19.2 105.1 -125.7 38.4 175.8 130.2 130.3 131.4 175.8 130.2 130.3 131.4 175.8 130.2 130.3 131.4 175.8 130.4 131 | 9 | | | ; | ; | | | |
| Initiate midcourse correction 35.2 19.2 105.1 -125.7 38.4 175.8 136.4 - Perform IMU alignment -72.3 62.4 -14.8 156.0 0.0 0.0 137.4 Complete IMU alignment -72.3 62.4 -14.8 156.0 0.0 0.0 147.1 Orient for CM/SM separation -72.3 62.4 -14.8 156.0 0.0 0.0 179.8 CM/SM separation 55.3 -2.2 -47.7 -87.3 45.0 0.0 68.2 | , oc. | | | o | 26.0 | | | Continue inertial hold |
| Perform IMU alignment -72.3 62.4 -14.8 156.0 0.0 0.0 137.4 Complete IMU alignment -72.3 62.4 -14.8 156.0 0.0 0.0 147.1 Orient for CM/SM separation -72.3 62.4 -14.8 156.0 0.0 0.0 147.1 CM/SM separation 55.3 -2.2 -47.7 -87.3 45.0 0.0 68.2 | • • • | | • | 40.9 | 26.3 | | | Continue inertial hold |
| Complete IMU alignment -72,3 62,4 -14,8 156,0 0,0 0,0 147,1 0 orient for CM/SM separation -72,3 62,4 -14,8 156,0 0,0 0,0 147,1 CM/SM separation 55,3 -2,2 -47,7 -87,3 45,0 0,0 68,2 | 18.4 | | • | 4 6.7 | | | 179.6 Continu | Continue inertial hold |
| Complete IMU alignment -72.3 62,4 -14,8 156,0 0,0 0,0 147.1 Orient for CM/SM separation -72.3 62,4 -14,8 156,0 0,0 0,0 179,8 CM/SM separation 55.3 -2,2 -47,7 -87,3 45,0 0,0 68,2 | | | | 52. 5 | -1.8 | 164.817 | -12.6 Performed in inertial hold | Performed in entry attitude, inertial hold |
| . Unioni for CM/SM separation -72.3 62.4 -14.8 156.0 0.0 0.0 179.8 CM/SM separation 55.3 -2.2 -47.7 -87.3 45.0 0.0 68.2 . | | | | 52, 7 | -1.8 | 164.8 -12 | -12.6 Continu | Continue inertial hold |
| CM/SM separation 55.3 -2.2 -47.7 -87.3 45.0 0.0 68.2 . | | | | 52.7 | | | | , |
| | -87.3 45.0 | 0.0 68.2 | • | | | | - | Vol. 145 3-1 |
| 0.0 0.0 114.0 | | | | | • | | Bed cht was care | 3 de 18 |

Table III. C-prime Lunar Orbit Mission IMU Matrices; Launch Date December 21, 1968; 72 Degrees Launch Azimuth

| h REFSMMAT | |
|-------------|---|
| <u>Y</u> | <u>z</u> |
| -0.30486116 | 0.49747632 7 |
| -0.45874422 | -0.87399866 |
| -0.83463367 | -0.27118908 |
| EFSMMAT | |
| <u> Y</u> | <u>Z</u> |
| 0.07638412 | -0.7571359 7 |
| -0.54928435 | 0.51108595 |
| 0.83213712 | 0.40686164 |
| REFSMMAT | |
| <u>Y</u> | <u>Z</u> |
| -0.01691802 | 0.84714425] |
| 0.44838224 | -0.46833652 |
| -0.89368179 | -0.251013 |
| | Y -0.30486116 -0.45874422 -0.83463367 EFSMMAT Y 0.07638412 -0.54928435 0.83213712 REFSMMAT |

Table IV. Scanning Telescope Sighting Targets

Launch Date: December 21, 1968

Landing Site: II-P-2

| Туре | Latitude | Longitude | Altitude (meters) |
|-------------------------------|----------|------------|-------------------|
| First control point landmark | 4.200° S | 164.300° W | 0.0 |
| Second control point landmark | 12.500°S | 151.500°E | 0.0 |
| Third control point landmark | 8.500° S | 96.000°E | 0.0 |
| Pseudo landing site landmark | 2.570° N | 35.000°E | -890.0 |
| | | | |

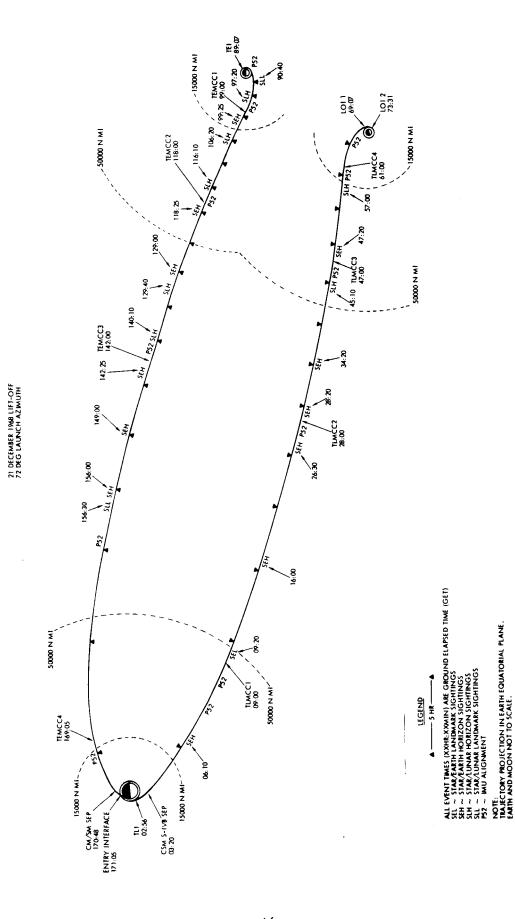
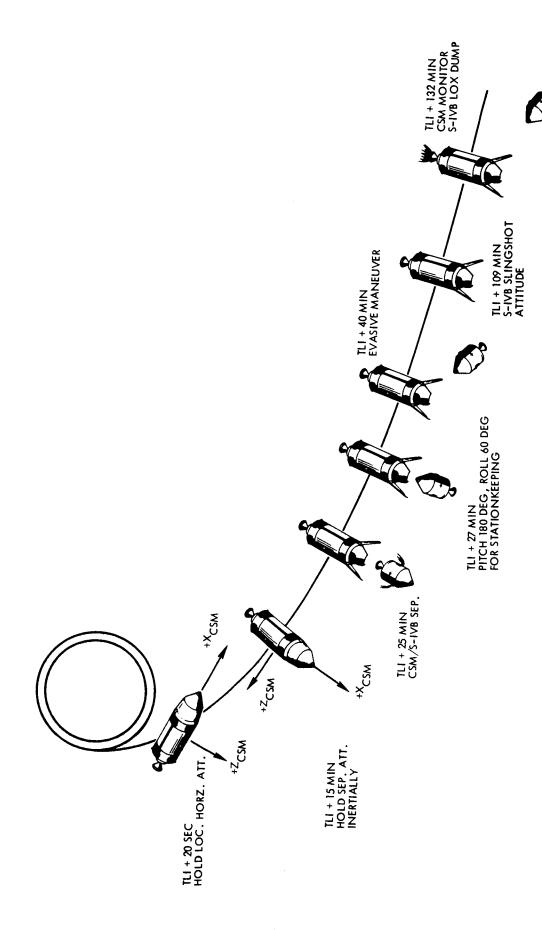


Figure 1. C-prime Lunar Orbit Mission Cislunar Trajectory and Event Profile



C-prime Lunar Orbit Mission Post-TLI Sequence of Events Figure 2.

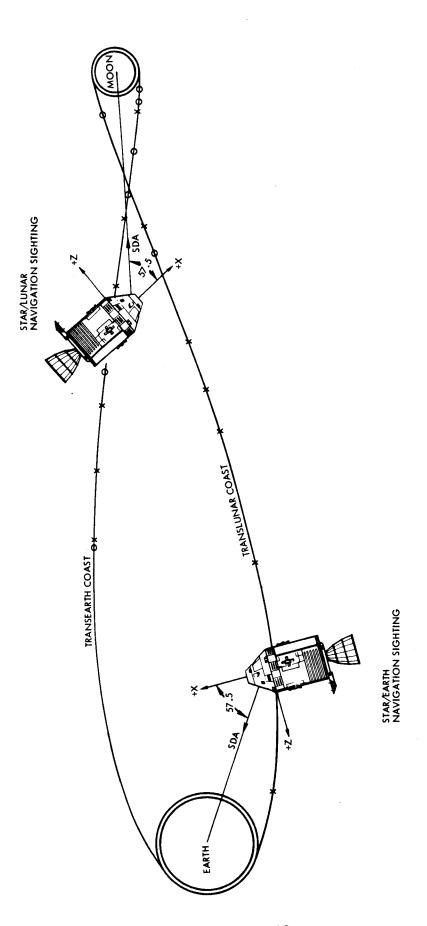


Figure 3. Cislunar Navigation Sighting Attitude Geometry

X ~ STAR/EARTH NAVIGATION SIGHTING O ~ STAR/LUNAR NAVIGATION SIGHTING

LEGEND

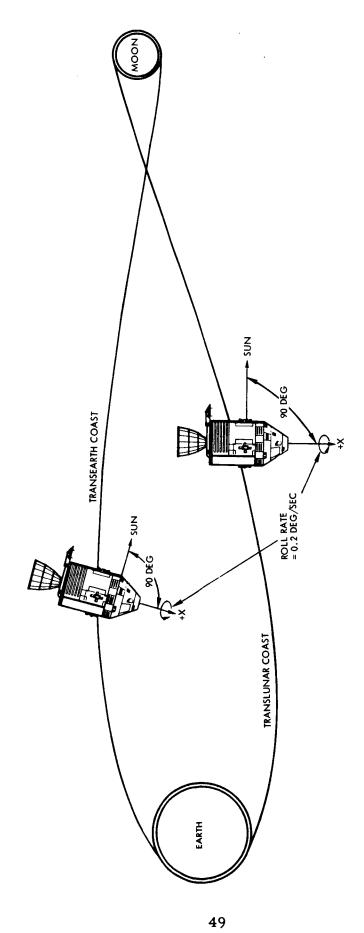


Figure 4. PTC Attitude Geometry

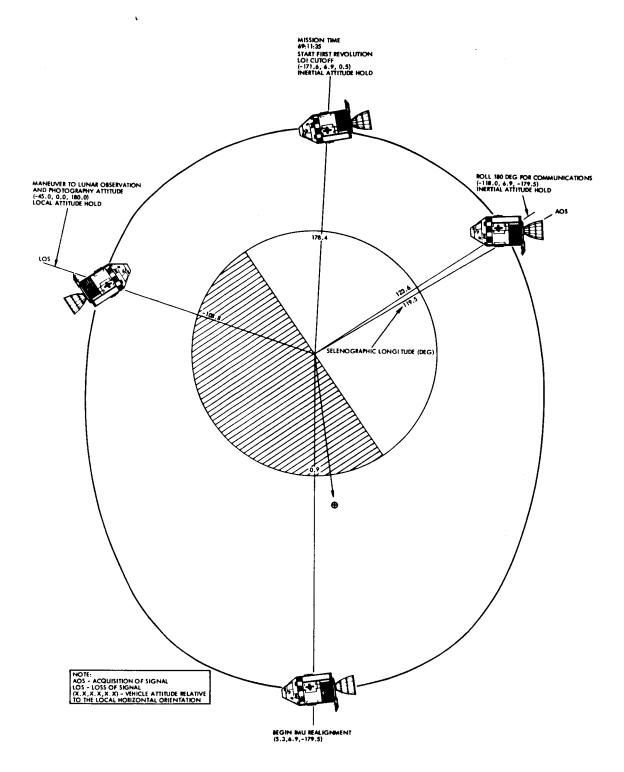


Figure 5. First Revolution Major Events and Attitudes

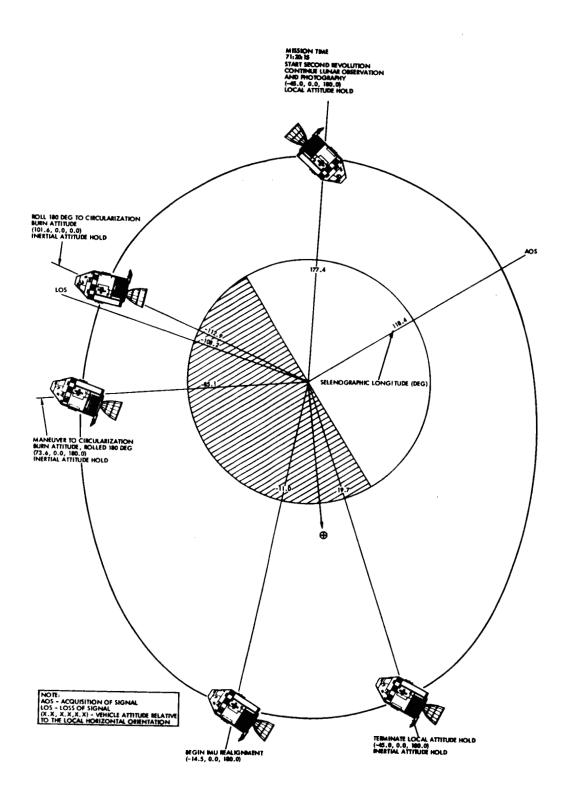


Figure 6. Second Revolution Major Events and Attitudes

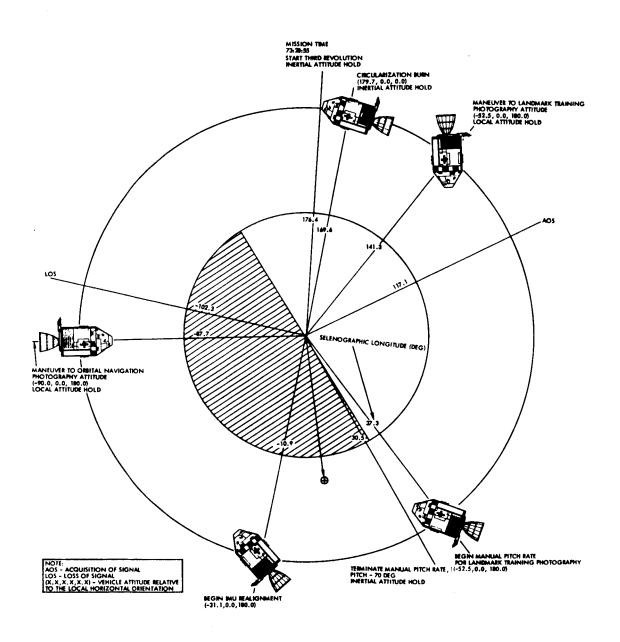


Figure 7. Third Revolution Major Events and Attitudes

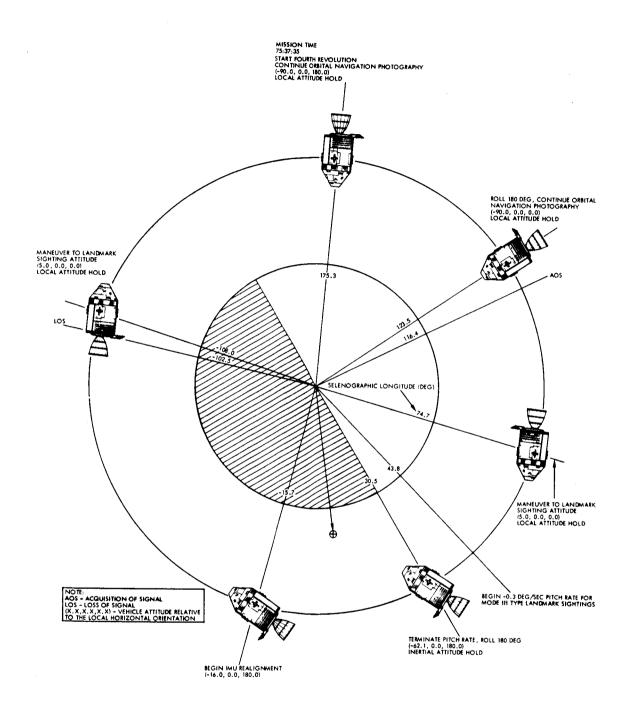


Figure 8. Fourth Revolution Major Events and Attitudes

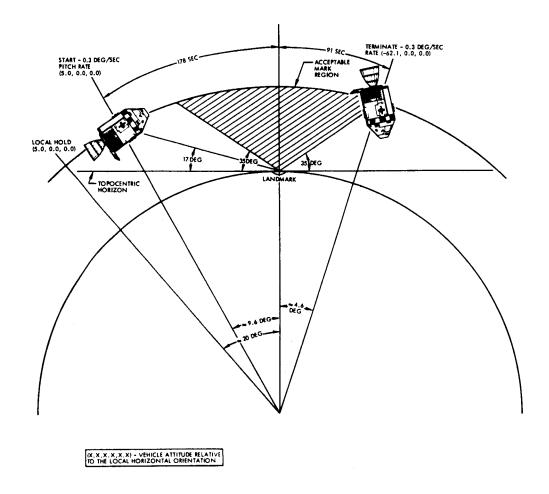


Figure 9. Mode III Type Landmark Sighting Attitude Sequence

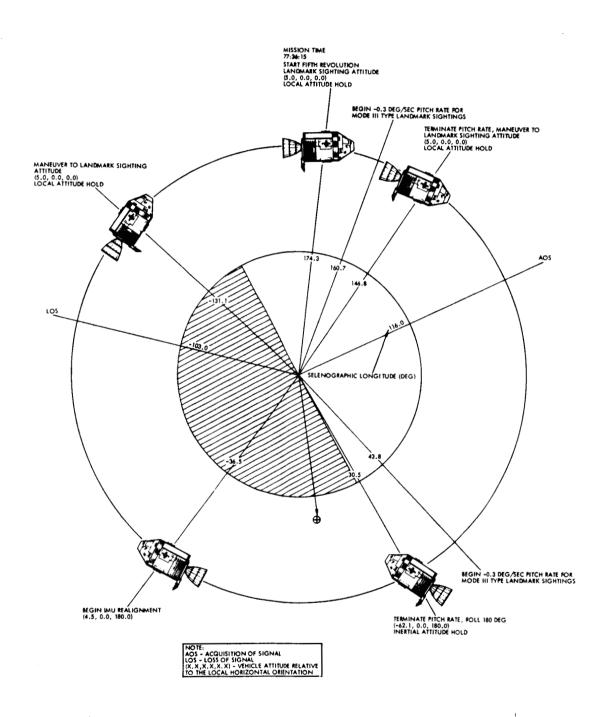


Figure 10. Fifth Revolution Major Events and Attitudes

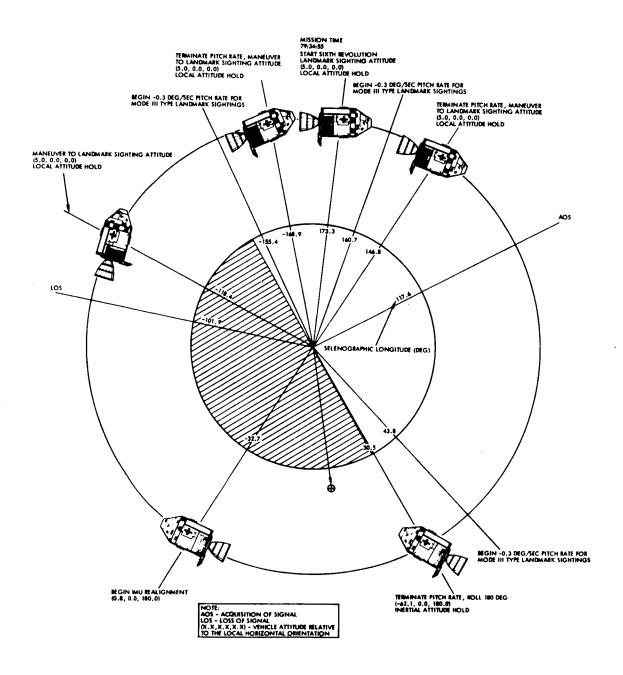


Figure 11. Sixth Revolution Major Events and Attitudes

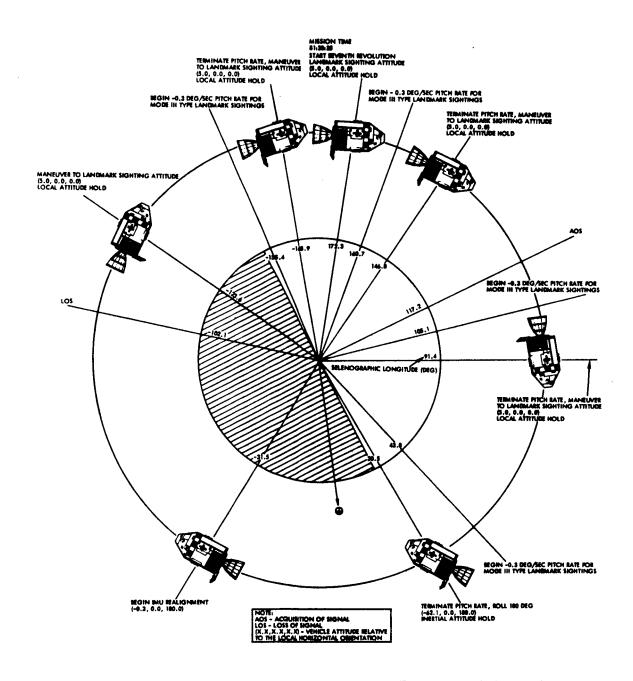


Figure 12. Seventh Revolution Major Events and Attitudes

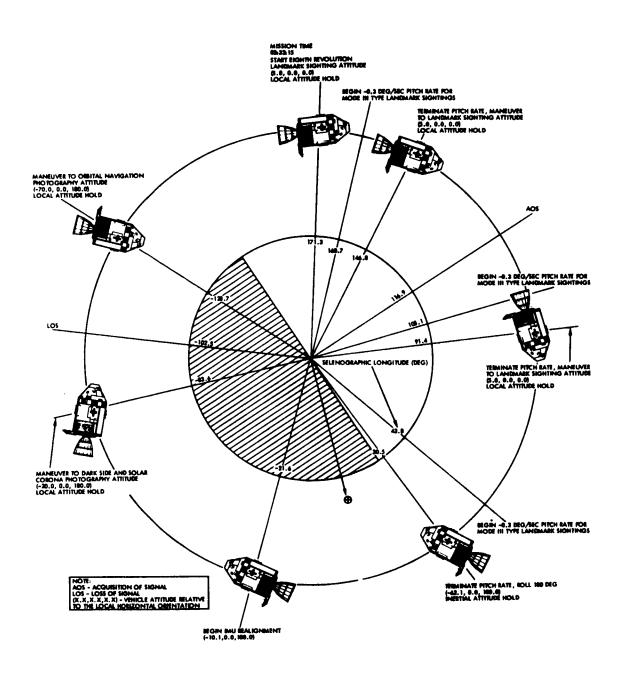


Figure 13. Eighth Revolution Major Events and Attitudes

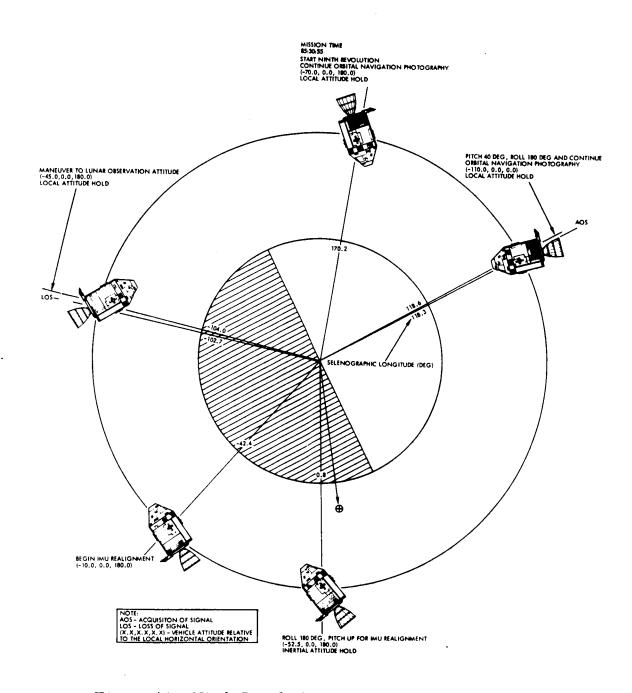


Figure 14. Ninth Revolution Major Events and Attitudes

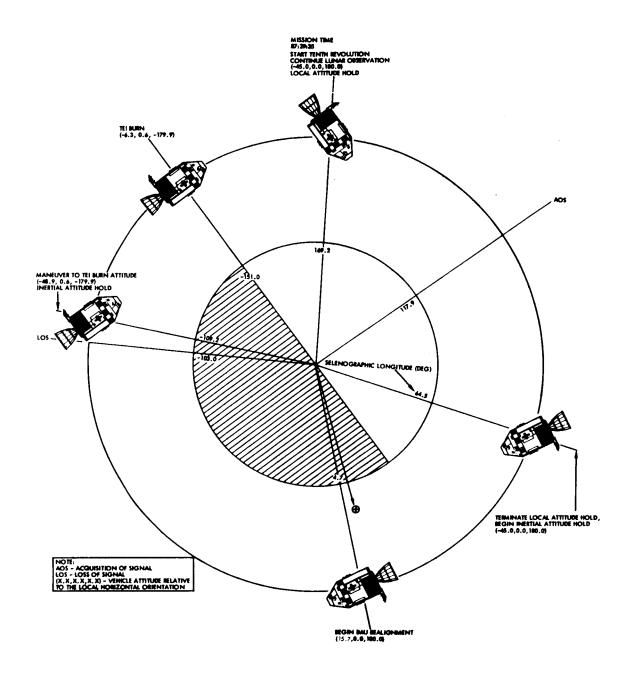


Figure 15. Tenth Revolution Major Events and Attitudes

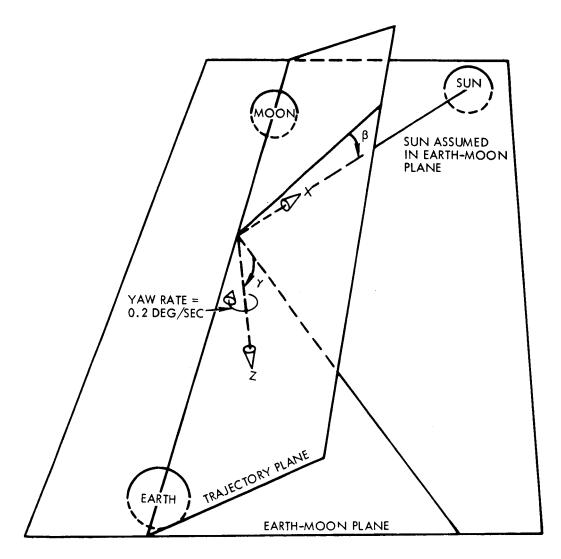


Figure 16a. PTC Tumble Mode Attitude Geometry

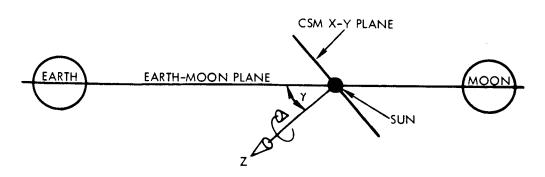


Figure 16b. PTC Tumble Mode Attitude Geometry as Viewed from the Sun

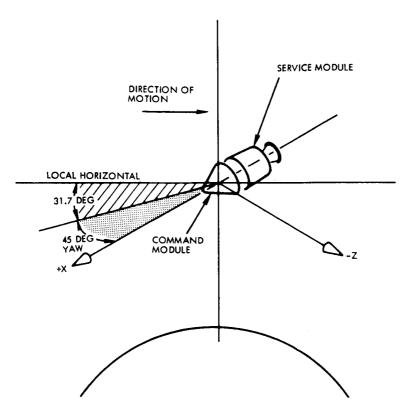


Figure 17a. CM/SM Separation Attitude

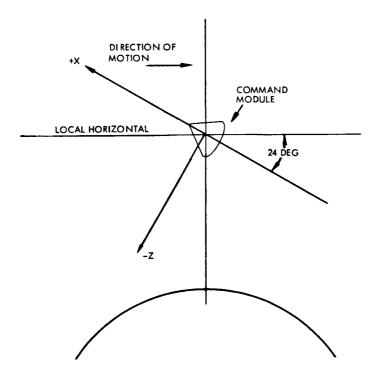


Figure 17b. CM Entry Attitude

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- G. W. Ricks: C'Mission Post TLI Sequence of Events. MSC Memorandum 68-FM55-303, October 7, 1968.